Tuna for Tomorrow ?

Some of the Science Behind an Important Fishery in the Pacific Islands

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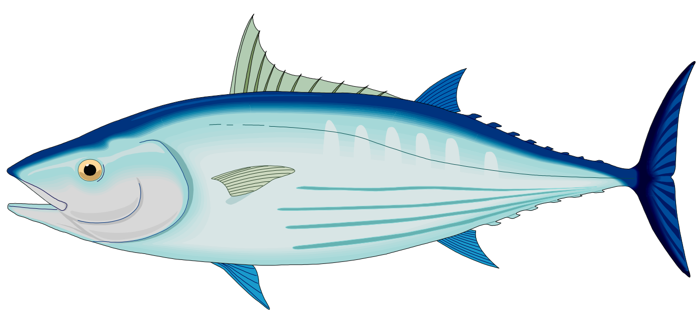
1. Introduction

Most people in the Pacific Islands realize that tuna is an important fishery resource for the region. There is less awareness, however, of the condition of tuna and sustainability of these resources for the future. We often hear of collapses of fish stocks in other parts of the world, and in this region, increases in tuna vessels, greater tuna catches, and mention of the possibility of over-fishing. The purpose of this paper is to summarize in non-technical terms what we know about tuna in the Pacific Islands, the health of this resource, and the major concerns for the future.

2. The Importance of Tuna

It is well known that fish and fishing are vital to the people of the Pacific Islands. Much of the nutrition, welfare, culture, recreation, government revenue, and employment are based on the region's living marine resources. What is less appreciated is that, not only is tuna an important group of fish for the Pacific Islands, the amount of tuna captured in the region is about ten times all other types of fish combined. In terms of value, the tuna catch is worth over seven times the value of all other Pacific Island fish catches combined.

It is also important to know that the Pacific Islands area and the wider Western and Central Pacific Ocean (WCPO) is the most important tuna fishing area in the world. Other regions which are important for tuna fishing are the Eastern Pacific, the Indian Ocean, and the Atlantic Ocean. The tuna catch in the WCPO region is much greater than that of the other three areas. In fact, the average annual tuna catch during the past ten years in the Western and Central Pacific is almost as much as the combined tuna catches of the Eastern Pacific, Indian, and Atlantic ocean.

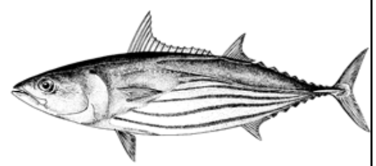
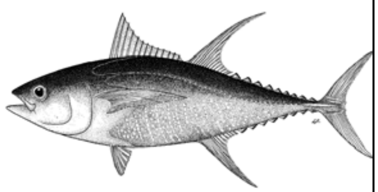
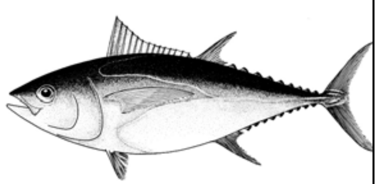
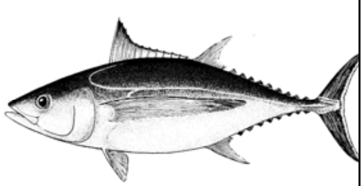


3. What is a Tuna?

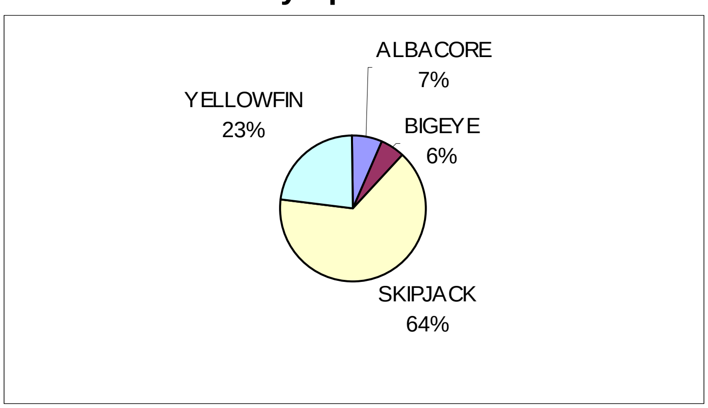
Tuna is not a single species of fish, but rather several species. Scientists often use the term "tuna and tuna-like fish" which includes a total of 61 species, fourteen of which are considered "true tuna". Four species are of major commercial importance in the Pacific Islands: skipjack, yellowfin, bigeye, and albacore.

These four species of tuna are quite distinct with respect to many properties such as how they are captured, the amount presently captured, the size of the populations, and the end use of the product.

The Main Tuna Species in the Region

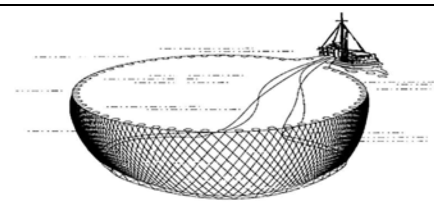
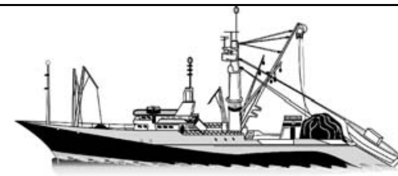
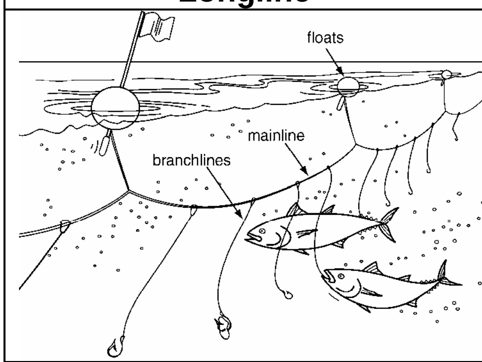
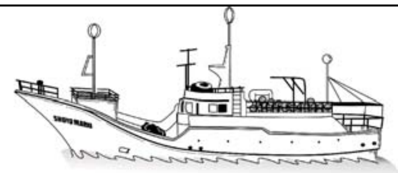
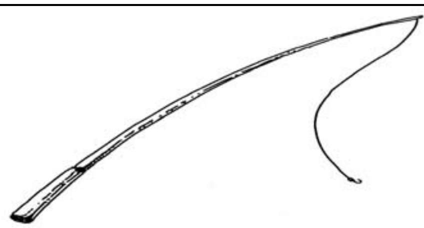
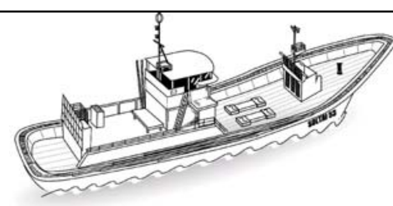
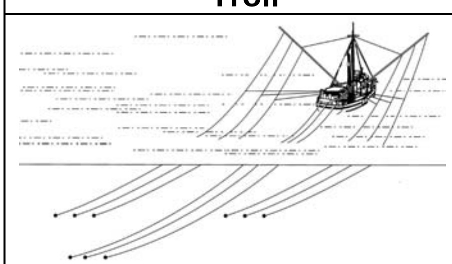
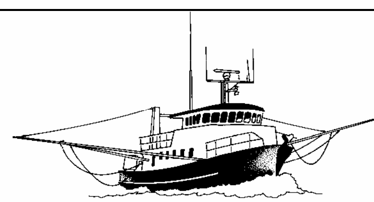
Tuna Species		Typical Size Captured	Annual Catch in the WCPO	Notes
Skipjack		40 to 70 cm	1,000,000 to 1,300,000 tonnes (mt); about 64% of the tuna catch of the region	Skipjack are caught mainly on the surface by purse seine and pole/line gear and used for producing canned tuna. Most fish caught are from one to three years old. In the WCPO there are more skipjack (biomass) than the other three main tuna species combined.
Yellowfin		40 to 70 cm and 90 to 160 cm	320,000 to 500,000 tonnes; about 23% of the tuna catch of the region	Small yellowfin are caught on the surface by purse seine and pole/line gear, while larger/older fish are caught deeper using longline gear. Small fish are used mainly for canning while high quality larger fish are often shipped fresh to overseas markets. Most fish caught are from one to six years old.
Bigeye		40 to 70 cm and 90 to 160 cm	80,000 to 120,000 tonnes; about 6% of the tuna catch of the region	Small bigeye are caught on the surface by purse seine and pole/line gear, while larger/older fish are caught deeper using longline gear. Small fish are used mainly for canning while high quality larger fish are especially valuable as fresh fish in the Japanese market. Most fish caught are from one to ten years old. Bigeye tuna account for a relatively small proportion of the total tuna catch in the region, but these tuna are extremely valuable; their economic value probably exceeds US$1 billion annually.
Albacore		60 to 110 cm	60,000 to 130,000 tonnes; about 7% of the tuna catch of the region	Small albacore are caught by trolling at the surface in cool water outside the tropics, while larger fish are caught deeper and mainly at lower latitudes using longline gear. Most of the catch is used for producing “white meat” canned tuna. Fish caught are typically from 1.5 to ten years old. This was the fish at the center of the driftnet issue.

Tuna Catch by Species in the WCPO



4. How Are Tuna Caught ?

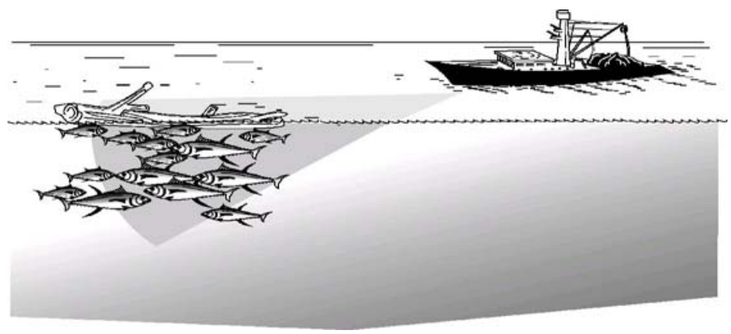
Tuna have been caught for centuries in the Pacific Islands. This was usually from canoes and often using handlines, troll gear, or pearl shell lures. Starting in the early 1900s larger scale tuna fishing gear was introduced into the region. Today four types of gear produces the vast majority of the tuna catch in the Pacific Islands region: purse seine longline, pole-and-line, and trolling.

Gear Type	Catch	Typical Vessel that Uses Gear	Notes
Purse seine			
	Mainly skipjack and small yellowfin are caught by purse seine gear. Most catch is for canning.		About 60% of the tuna catch in the WCPO region is by purse seine gear, about 1.2 million tonnes in 2003. Most of the purse seine catch is taken within 5 degrees of the equator.
Longline			
	Most tuna caught are large size yellowfin, bigeye, and albacore. The prime yellowfin and bigeye often are exported fresh to overseas markets. Most of the albacore is for canning.		About 11% of the tuna catch in the WCPO region is by longline gear, about 213,000 tonnes in 2003. There are two major types of longliners: (1) relatively large vessels with mechanical freezing equipment (often based outside the Pacific Islands), and (2) smaller vessels that mostly use ice to preserve fish and are typically based at a port in the Pacific Islands.
Pole-and-line			
	Mainly skipjack and small yellowfin are caught by pole-and-line gear. Most catch is for canning or producing a dried product.		About 15% of the tuna catch in the WCPO region is by pole-and-line gear, about 295,000 tonnes in 2003. In the 1980s several Pacific Island countries had fleets of these vessels, but most no longer operate due to competition with the more productive purse seine gear. Most of the catch by this gear in is made in Asian waters.
Troll			
	Large-scale trolling targets albacore for canning.		Gear types other than the three listed above are responsible for about 13% of tuna catch in the WCPO. Large-scale trolling is an important part of this. It is carried out in the cool water to the south and north of the Pacific Islands region. Trolling in the south results in about 5,000 tonnes of albacore annually.

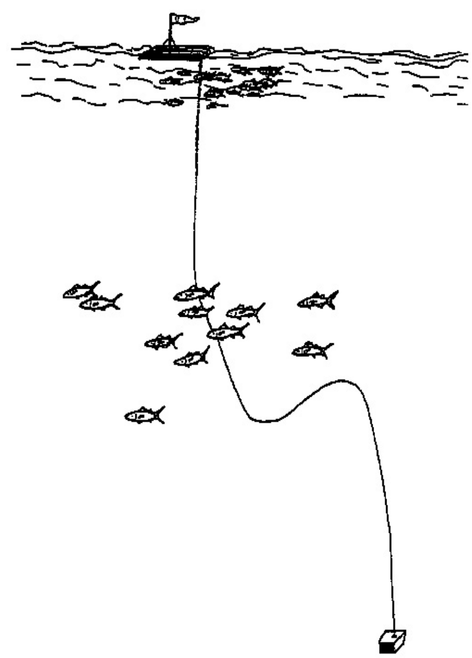
5. Floating Objects and Fish Aggregation Devices

Although not really a "gear type" or "fishing method", objects that are floating in the ocean are important in tuna fishing. For reasons still unknown to science, almost anything floating in the ocean tends to attract tuna and several other types of fish – sometimes in very large quantities. Tuna fishers know that tuna catches can be very good around objects floating offshore - especially ones that have been in the water for several weeks. Purse seine fishermen seek floating objects as they can set their nets and capture the attracted tuna, sometimes over 100 tonnes from a single set (25,000 fish of 4 kg). In some years, nearly half of the purse seined tuna in the Pacific Islands region is caught in association with floating objects.

There are several types of floating objects of significance in tuna fishing. The most common is simply a log. Logs floating in the ocean are found mainly often in the western part of the Pacific Islands region because rivers (the way most get carried out to sea) are common in the large Melanesian islands.



Another form of floating object is a "fish aggregation device" or FAD. This is simply a man-made object placed in the ocean specifically for the purpose of drawing fish to an area. In some cases the FAD is anchored (lots of anchor line is required in the open ocean) or drifting.



An important point about FADs and logs is that, in addition to attracting tuna, they also attract other fish - the non-tuna catch by purse seiners is much larger around these objects than when setting nets on free-swimming tuna schools. The catch of small tuna is also much greater around FADs and logs, which is significant at present when efforts are being made to reduce fishing on small bigeye and yellowfin. Bigeye, which are currently of most conservation concern, are only captured in significant quantities by purse seiners when setting on floating objects – they are rarely captured in sets on free-swimming schools.

Box: What's Happening in the Three Major Tuna Fleets of the Pacific Islands ?

Purse seine fleet: About 200 purse seiners operated in 2003 in the Pacific Islands region. The main fleets are from Taiwan, Japan, Korea, USA, Vanuatu, and the Philippines. Vessels from 13 other countries are also active. The combined fishing power of all purse seine vessels fishing in the Pacific Islands increased about 67% during the 1988 to 2003 period

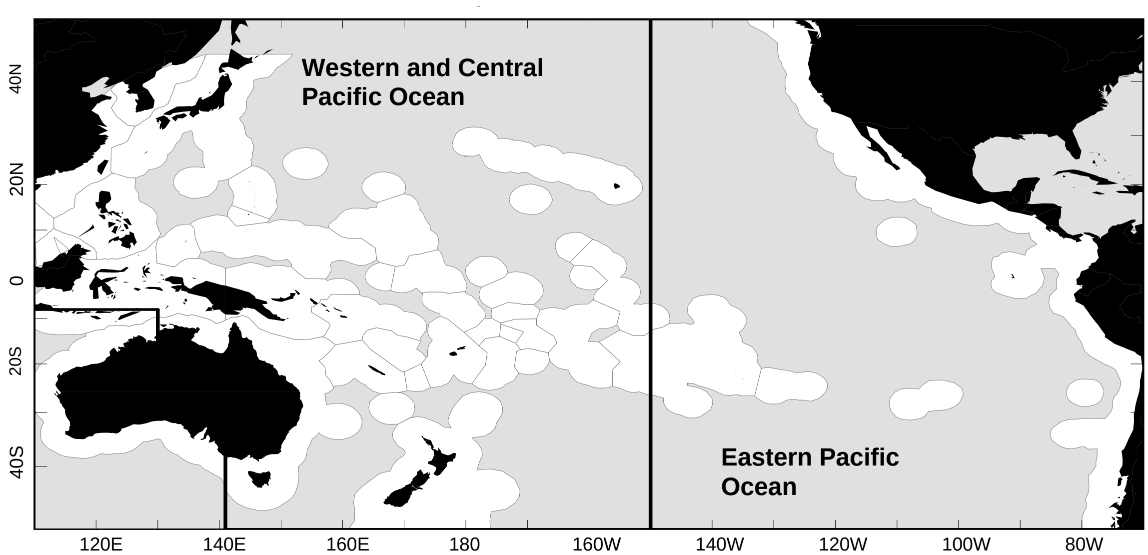
Longline fishery: The total number of longline vessels has fluctuated between 4,000 and 5,000 since the mid 1970s, and has remained close to 5,000 since 1992. In recent years, there has been a gradual increase in the number of Pacific Islands domestic vessels, such as those from American Samoa, Cook Islands, Samoa, Fiji, French Polynesia, New Caledonia and Solomon Islands. These fleets mainly operate in their respective exclusive economic zones (EEZs) with albacore being the main species taken.

Pole-and-line fishery: Economic factors and technological advances in the purse seine fishery (primarily targeting skipjack) have seen a gradual decline in the number of pole-and-line vessels in the pole-and-line fishery and stabilisation in the annual catch during the past decade. Most of the Pacific Islands domestic fleets (Palau, PNG and Kiribati) are no longer active, with only one vessel operating seasonally in Fiji. About ten pole-and-line vessels continue to operate in the Solomon Islands.

6. The "Region"

When we discuss tuna catches, the "region" in question needs to be carefully defined, as different geographic areas are often used. In increasing size, the various regions used for tuna catches could be a 200-mile zone of an individual country, the combined zones of Pacific Island countries, or the western and central Pacific Ocean. This latter area, frequently called the WCPO, is often used when discussing regional tuna catches. It includes the Pacific Ocean waters of Indonesia, Philippines, Japan, USA (Hawaii and western Pacific territories) and considerable areas of international waters. The tuna that occur in these areas are from the same stocks that occur in the EEZs of Pacific Island countries.

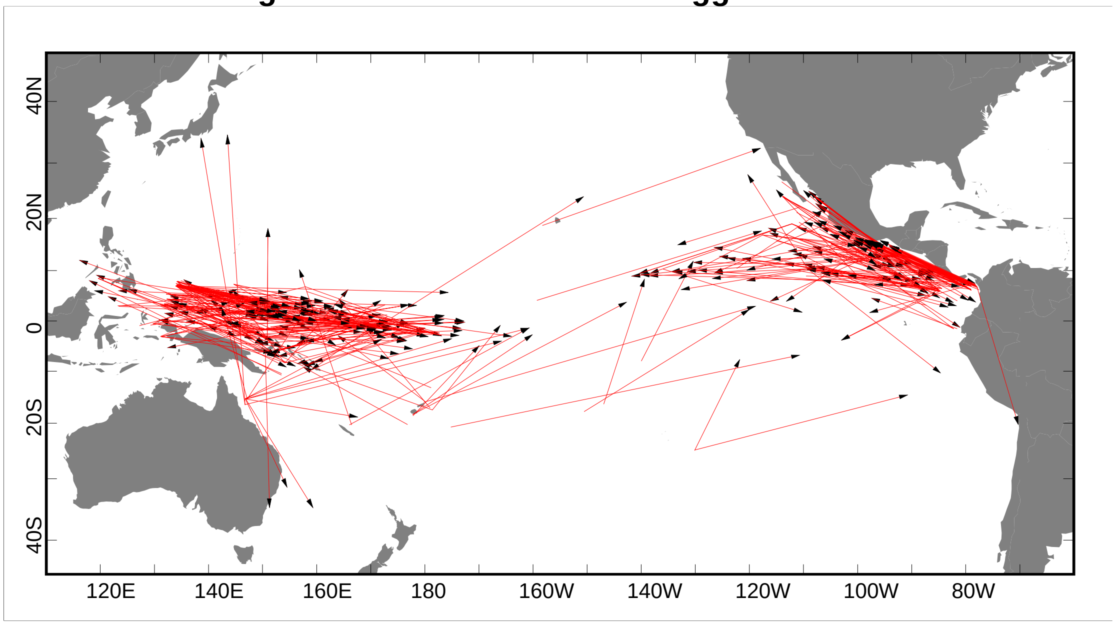
The Boundaries of the Western and Central Pacific Ocean



7. Tuna Movement

One of the reasons why a very large region (French Polynesia to Indonesia) is used for tuna catch statistics is that tuna have the capability to move considerable distances and that catches in one country could potentially have some impact in an area thousands of miles away. As an example, the figure below shows the movements of yellowfin that were caught, marked with a plastic tag, released, and then re-captured at a later date.

Long-Distance Movements of Tagged Yellowfin



Because the four main species of tuna have the ability to move great distances, they are sometimes called “highly migratory”. Some aspects of this concept should be noted:

- Although these fish can move great distances, most of the tagged tuna were actually re-captured close to the locations where they were tagged. The figure above shows just the long-distance movements, when there were actually many more short distance movements.
- Tagging data show that there is considerable movement of tuna between the waters of adjacent countries. Using information from tagging and other studies, scientists can now estimate how much tuna in one area have come from a neighboring area.
- Although tag recapture information is interesting and can show some important characteristics of tuna, the most powerful use of tagging data occurs when it is combined with other data such as those concerning tuna growth, mortality, and catches to give an over-all picture of the condition of the resource. (more on this topic later in this paper)

Box: Some Terms Often Used in Studying Fisheries

An understanding of some of the science associated with studying fisheries is made easier with a knowledge of the following terms:

- **Biomass** – The total physical weight of a group of fish.
- **Fish population** or **fish stock** – A unit of a single species of fish that is at least partially isolated from other fish of the same species in other areas.
- **A fishery** – Fishing for a kind of fish, such as the albacore fishery. This is often further broken down by such classifications as gear type and area as in, for example, the South Pacific albacore troll fishery.
- **Ecosystem** – The biological and physical environment in which a particular species or group of species lives. The pelagic ecosystem inhabited by tuna comprises the water masses of the various current systems, as well as the diverse biological components of these areas - from phytoplankton, zooplankton and small baitfish to the large upper predators such as tunas, billfishes and sharks.
- **Fishery management** – Doing something to achieve objectives that have been set for a fishery, such as limiting fishing when conservation has been established as an objective. Charging license fees when increasing government revenue is an objective is another example.
- **Fleet** – A group of similar fishing vessels, such as the Japanese purse seine fleet.
- **Fishing effort** – A measurement of the amount of fishing, as one purse seiner fishing for one day.
- **Model** – A simple mathematical description of something. Most fishery models enable predictions (such as fish catch) when inputs (such as fishing effort) are specified.
- **Mortality** – The rate at which fish are dying from either natural causes (natural mortality) or from fishing (fishing mortality).
- **Pelagic** – The open ocean environment, as distinct from coastal or inshore. The four main species of tuna in the region are considered pelagic as they are found far from shore.
- **Recruitment** - The growth and entry of small fish into a size category that can be captured by fishing gear.
- **Stock assessment** – The analysis of information collected to assess the health of a fish population.

8. Tuna Catches

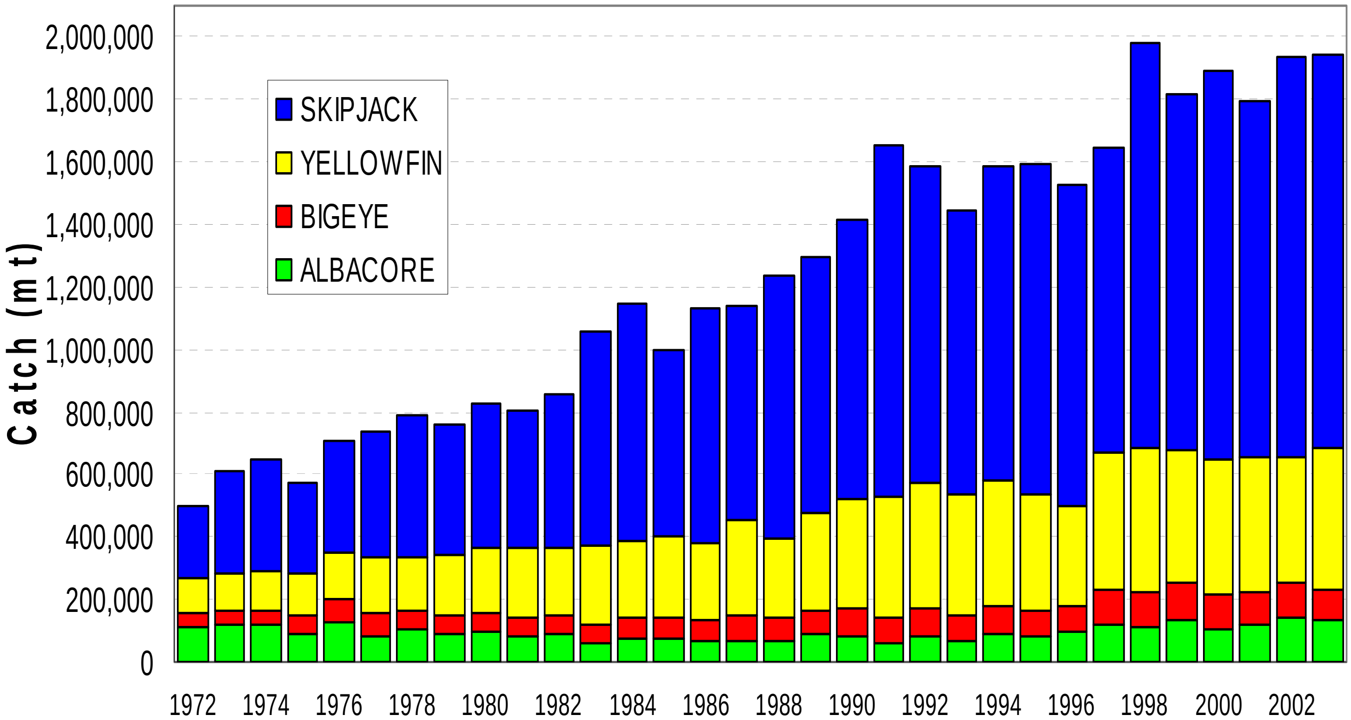
Tuna catches in the Pacific Islands are estimated in a variety of ways. These include:

- Information from the governments of the fishing nations
- Catch details from the logbooks that the operators of fishing vessels are required to fill out each day
- Observations from individuals placed on board fishing vessels (fishery observers)
- The monitoring of the unloading of tuna at important ports

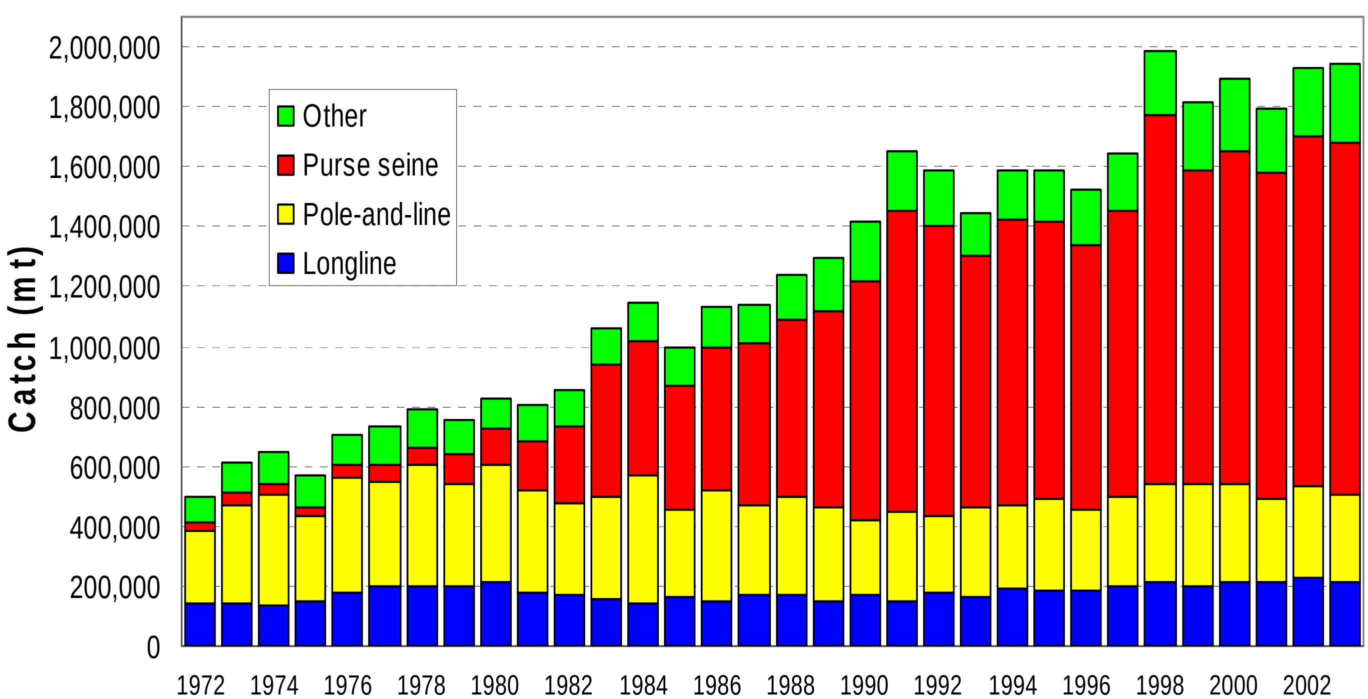
A single tuna fishing vessel can fish in the waters of several countries during one fishing trip. For this and other reasons, some form of regional coordination is required when compiling tuna catch data. This role has been carried out for more than two decades by the Oceanic Fisheries Programme, an important entity within the Secretariat of the Pacific Community (SPC), one of the regional organizations with fishery responsibilities (see Box).

The SPC has recently compiled estimates of the tuna caught in the WCPO region. This information can be summarized in a variety of ways, but it is often useful to show it as (a) catch by species, and (b) catch by gear type.

Tuna Catches by Species



Tuna Catches by Gear Type



The magnitude of two million tonnes of tuna shown on the above graphs may not be easy to grasp. The tuna catch consists mainly of fish ranging in weight from one to over 150 kg. If all fish were six kilos, then this two million tonnes tuna would represents over 330 million individual fish.

The WCPO tuna catch data graphed above shows a number of features:

- The catch in the region has increased tremendously during the last three decades – almost 4-fold since 1972.
- With respect to gear, purse seining is responsible for most of the increase.
- With respect to species, skipjack (and to a lesser extent yellowfin) is responsible for most of the increase.

A major issue in tuna fisheries concerns the sustainability of the catches. Can the very large tuna catches in the WCPO continue into the long-term future? There are obviously limits – tuna catches cannot expand forever as they have for the past thirty years – but where are those limits? At what point should we be concerned about over-fishing? These and related questions occupy much of the attention of the scientists that study tuna resources.

Box: Fisheries and the Regional Organizations in the Pacific Islands

Compared to other fishing regions of the world, an important feature of the Pacific Islands area is the strong regional organizations active in the fisheries sector. The two main ones are:

- Secretariat of the Pacific Community. SPC, based in Noumea, New Caledonia, assists its member countries and territories in matters relating to (a) coastal fisheries development and management, and (b) scientific research and catch data compilation on the tuna resources of the region.

- The Forum Fisheries Agency. The FFA, based in Honiara, Solomon Islands, assists its member countries in matters dealing with the management of the region's tuna resources, including economics, surveillance, and legal aspects.

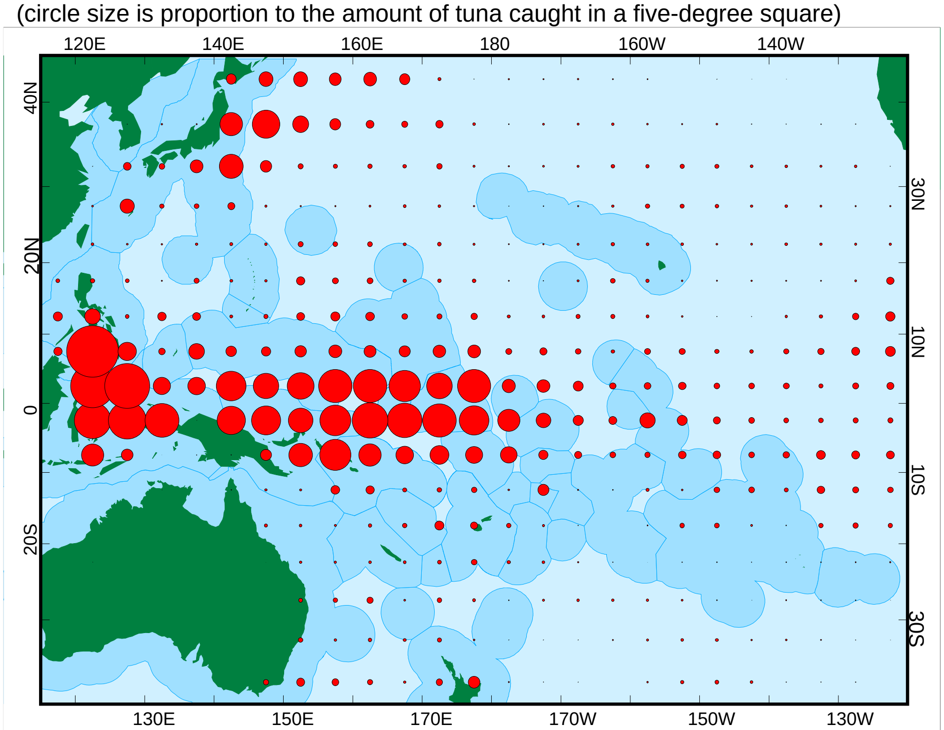
Other regional organizations also have responsibilities in fisheries. These are the South Pacific Regional Environment Programme (based in Apia, Samoa), the South Pacific Applied Geoscience Commission (Suva, Fiji), and the University of the South Pacific (Suva, Fiji).

9. Where Are Tuna Caught ?

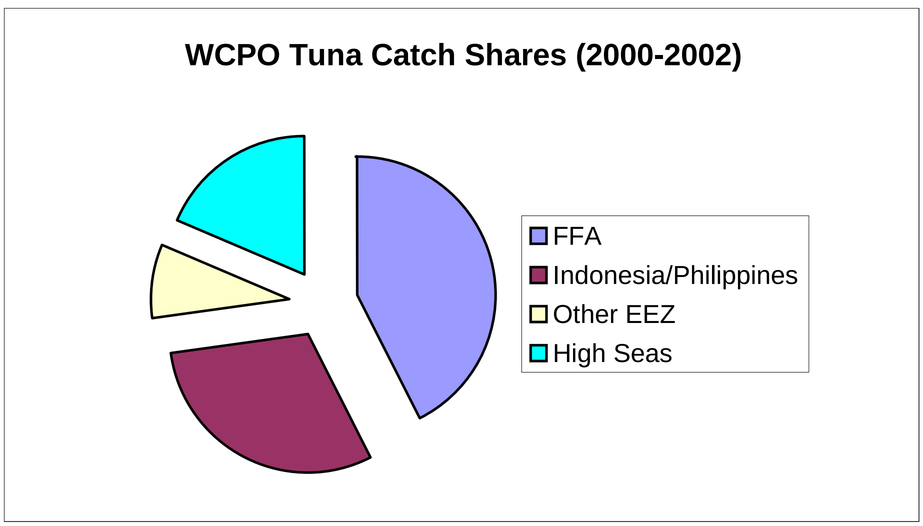
The location where the catch is made is important. Although tuna fishing occurs in every country of the region, the catch is not evenly distributed. The chart below shows that most of the catch is taken close to the equator. One of the reasons for this is the greater feasibility of purse seining that area.

Location of the Tuna Catches in the WCPO

(circle size is proportion to the amount of tuna caught in a five-degree square)



The pie chart below shows that much of the catch occurs within the exclusive economic zones of FFA member countries (the independent Pacific Island countries). The large share in Indonesia and the Philippines is also significant, especially since tagging data show much interchange of fish between the waters of those two Southeast Asian countries and those of the Pacific Islands. The catch on the high seas is also very important as placing any controls on that fishing is more complex than doing so in waters under the control of a single country.



10. Biology of the Beasts

Before we look at tuna catch sustainability in the region, it may be helpful to examine some biological characteristics of tuna – those features of the different species of tuna that may affect the amount of fishing which can be supported. Key characteristics common to the four important species of tuna are:

- Elevation of body temperature – Unlike most fish, these tuna have body temperatures that are higher than that of the sea water in which they live. This has important implications for the vertical and horizontal movement of tuna, their food requirements, and, in conjunction with oceanographic features, the manner in which the fish are best caught.
- Abundant spawning - A spawning female tuna releases about 100,000 eggs per kilogramme of body weight. Because there is so much spawning by a single fish, there is usually no strong relationship between the number of spawners and subsequent number of new fish entering the fishery.
- Variable recruitment – The survival of the eggs, larvae, and juvenile tuna to a size that can be captured by fishing is highly dependent on environmental features. This can result in large variations in the amount of adult fish.

Skipjack, yellowfin, bigeye, and albacore also each have individual characteristics that have an important effect on the fishing pressure they can sustain:

Skipjack This species is found year-round concentrated in the tropical waters of the WCPO. Its distribution expands seasonally into subtropical waters to the north and south. It is a species characterized by large stock size, fast growth, early maturation, prolific and year-round spawning over a wide area, relatively short life span and highly variable recruitment into a fishable size. It is assumed that skipjack in the WCPO is a separate population (for stock assessment and management purposes) to those in the eastern Pacific.

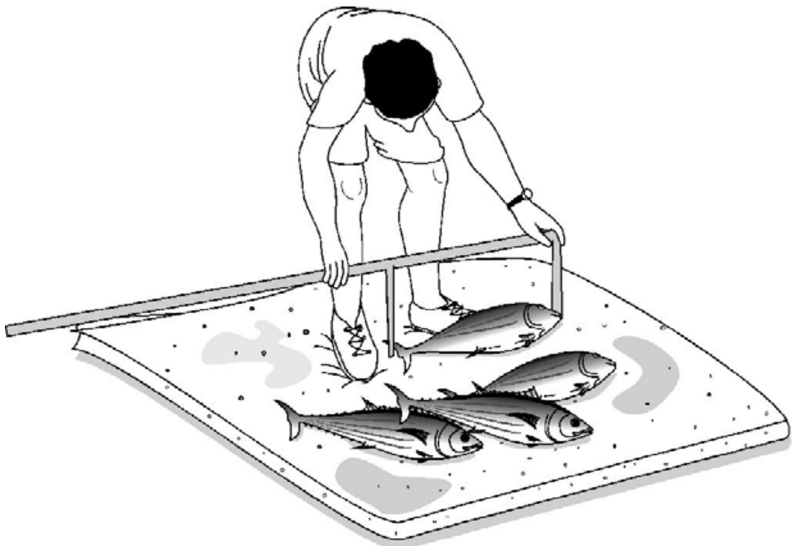
Yellowfin These tuna are fast growing, mature at about two years of age and spawn prolifically. Yellowfin can grow to over 100 kg at an age of six years or older. The majority of the catch is taken from the equatorial region where they are harvested with a range of gear types, predominantly purse seine and longline. For stock assessment purposes, yellowfin tuna are believed to constitute a single stock in the WCPO.

Bigeye This species has a moderate growth rate and matures at approximately three to four years of age. Bigeye are known to grow up to about 200 cm and 180 kg when eight years or older. They have a wide distribution between 40°N and 40°S and vertically between the surface and 500 m deep (occasionally to 1000 m) due to their tolerance of low oxygen levels and low temperatures. These and other characteristics make them less resilient to exploitation than skipjack and yellowfin. The geographical distribution of bigeye is continuous across the Pacific. However, it has been noted that there are areas of lower catch separating the principal fishing areas in the eastern (east of about 165°W-170°W) and the more western regions of the Pacific. Large fish are caught mainly by longline, and these longline-caught bigeye are the most valuable among the tropical tunas. Juvenile fish tend to form mixed schools with skipjack and yellowfin, which results in catches by the surface fishery, particularly in association with floating objects. Natural mortality is estimated to be relatively low compared with other tropical species.

Albacore These tuna are segregated into two discrete stocks in the WCPO, with the equatorial area (where albacore are rare) separating the southern component from those of the north. Mature albacore (age at first maturity is about 4 to 5 years) spawn in tropical and sub-tropical waters between 10 to and 25 degrees from the equator, with individual fish becoming available to surface fishing about 40 degrees from the equator approximately one to two years later, at a size of 45–50 cm. From this area, albacore appear to gradually disperse towards lower latitudes, but may make seasonal migrations between tropical and sub-tropical waters. Albacore are relatively slow growing, and have a maximum length of about 120 cm. Natural mortality is low compared to tropical tunas, with significant numbers of fish reaching an age of 10 years or more.

11. Size Composition of the Tuna Catch

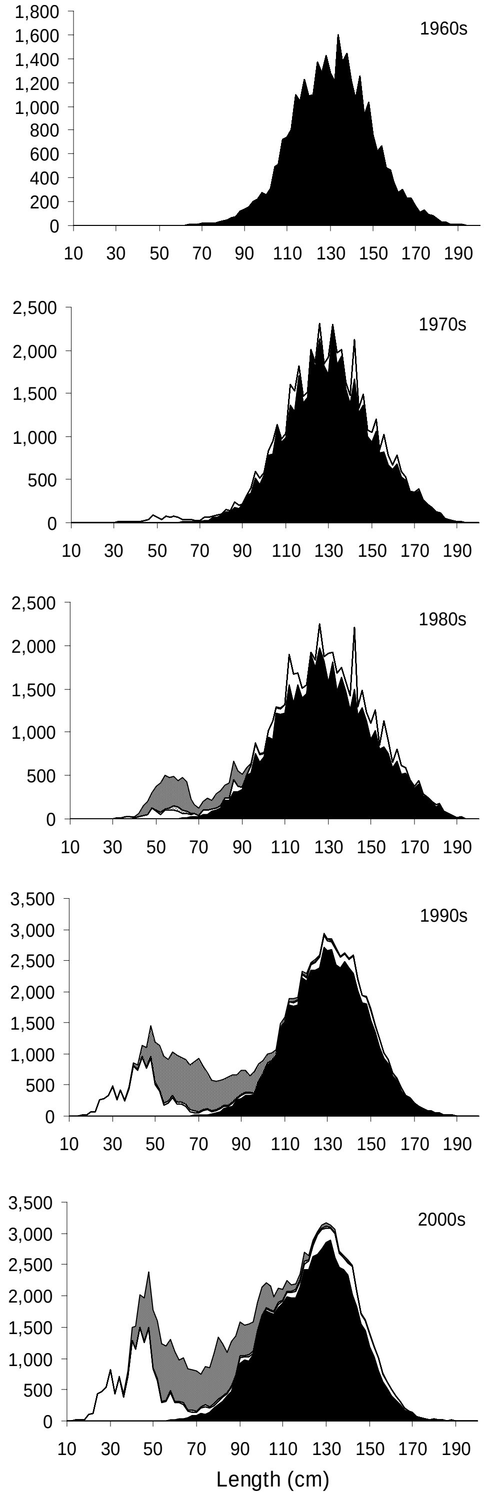
As fishing on a stock of fish increases, the size distribution of fish in the catch sometimes changes - usually with a decline in the proportion of large fish. It is often useful to monitor the size composition of the catch as a potential indicator of the impact of fishing. Other factors, however, such as the number of juveniles growing into the fishery and changes in fishing methods, may also impact the catch size composition.

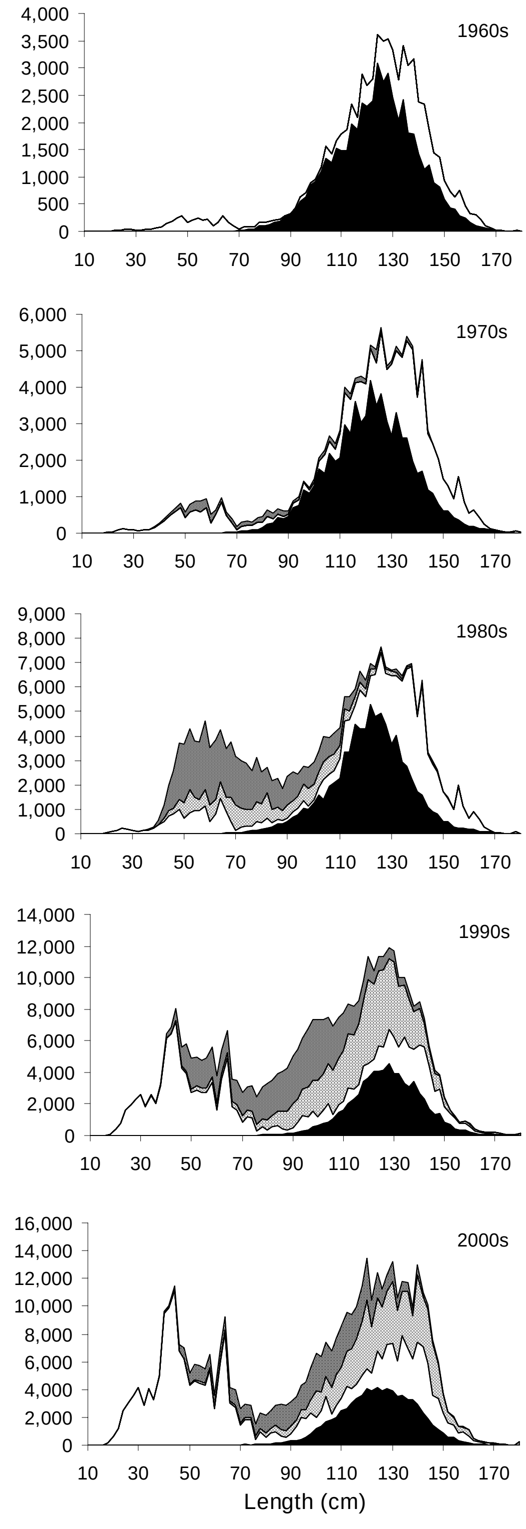


On the figures below, we can see the size composition (measured in tonnes per 2 cm size class) for bigeye and yellowfin over five decades.

Some of the apparent trends over time in the size of tuna seem to be related to fishing methods or recruitment, such as the small yellowfin in the catches in the 1990s and 2000s. The decrease since the 1960s in the proportion of very large fish (yellowfin greater than 150 cm; bigeye greater than 170 cm) is typical of a fishery in which fishing pressure is increasing.

Like tagging information, size composition data by itself can be informative, but its most powerful use is when it is combined with other data affecting the fish population (catch, effort, tagging data and biological information) to give an over-all picture of the condition of the resource.





Bigeye[1] **Yellowfin**

[1]Key to figure:

- Histograms are measured in tonnes per 2 cm size class
- Bigeye – black: Longline; white–Phil-Indo fisheries; grey: purse seine associated; hatching: purse seine; unassociated catches are negligible
- Yellowfin – black: Longline; white: Phil-Indo fisheries; grey: purse seine associated; hatching: purse seine unassociated

12. Tuna Fisheries, the Pelagic Ecosystem, and the Environment

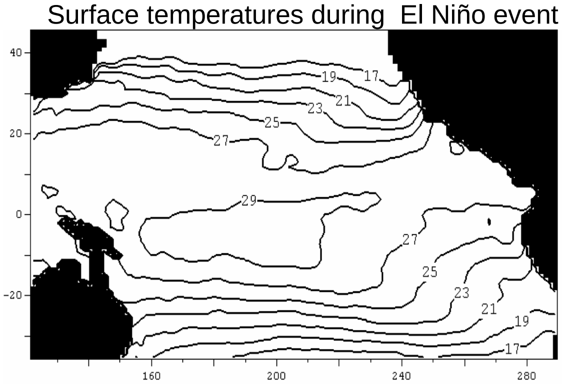
In a discussion of tuna fisheries of the Pacific Islands region, it is necessary to consider the relationship of the fishing activities to the other components in the ecosystem in which tuna is a part. Two important aspects of this are (1) the effects of the environment on tuna, tuna fishing and the wider pelagic ecosystem, and (2) the effects of tuna fishing on the ecosystem.

12.1 The Effects of the Environment on Tuna, Tuna Fishing and the Ecosystem

Although a general connection between atmospheric/oceanographic processes and tuna distribution has been recognized for some time, only in the past few decades have the details been clarified. In the Pacific Islands region, the most striking relationship seems to be between the climatic event known as El Niño and tuna, including their recruitment, abundance, distribution, and ease of capture.

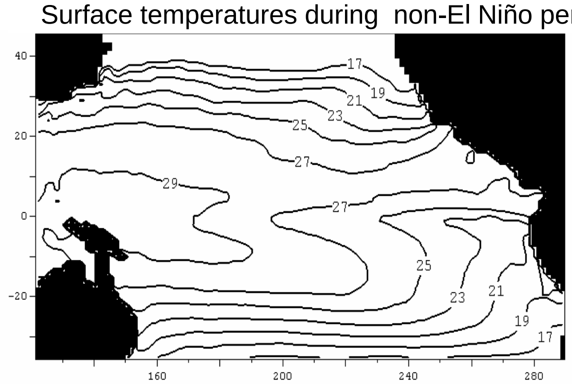
An El Niño event is a dynamic interaction between the atmosphere and ocean in which many large-scale processes occur. During such events, the warm equatorial waters of the western part of the Pacific Islands region (north and northeast of Papua New Guinea) expand eastwards towards Latin America. (see diagram below).

Surface temperatures during El Niño event



Warm water (29^0) extends towards Latin America

Surface temperatures during non-El Niño period

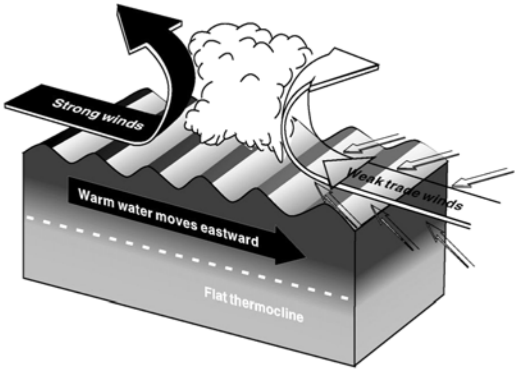


Warm water is restricted to western equatorial area of WCPO

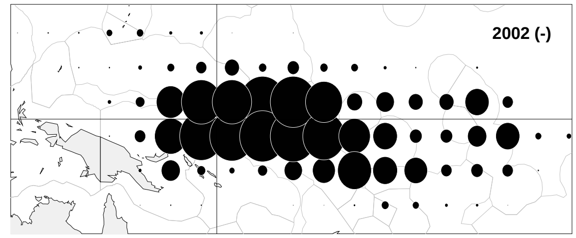
The vertical temperature features of the ocean also change. The thermocline (a horizontal layer in the water column within which there is a rapid temperature change from the warm surface to the cool underlying water) tends to be relatively deep in the Pacific Islands area. During an El Niño event, the thermocline becomes more shallow in the WCPO and this tends to restrict the vertical movement of tuna schools, making them more vulnerable to capture by purse seine gear than in non-El Niño periods (referred to as La Niña).

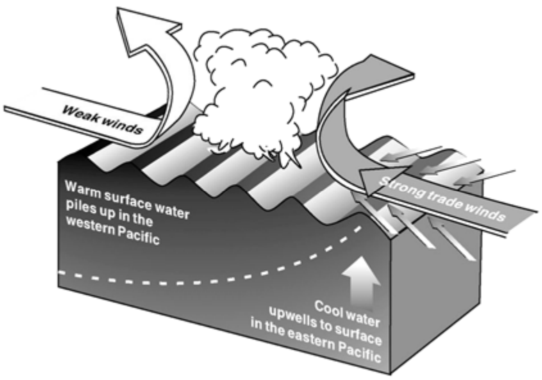
The schematic diagram below shows the wind, current, and ocean temperature changes that occur during an El Niño period. The maps to the right show that the area of tuna purse seining during an El Niño (for example, 2002) tends to spread eastward from where such catches normally occur in a La Niña year (2000).

Oceanograpy/Climate Aspect **Tuna Purse Seine Catch Aspect**

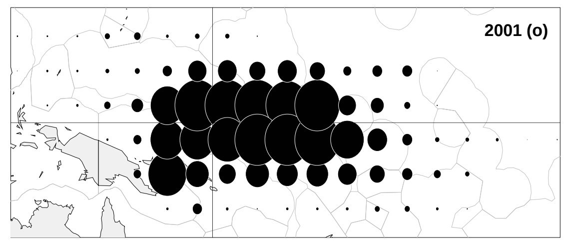


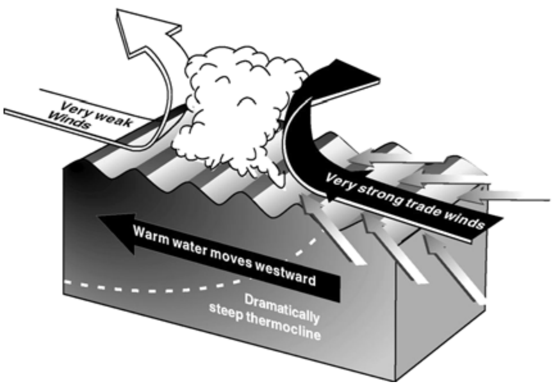
El Niño



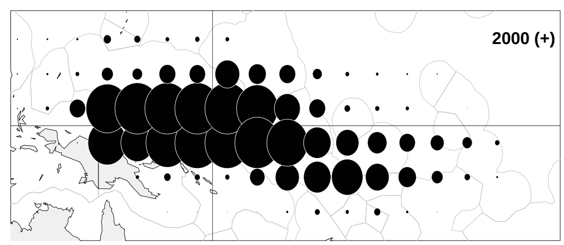


Transition





La Niña



Although it can be seen that the areas of tuna purse seining move in an El Niño period, less obvious changes having a large effect on tuna also occur. Shifts in the ocean temperature and currents cause huge changes in nutrients available for organisms at the bottom of the food chain and this eventually becomes reflected in the food available for tuna and other upper-level predators. Scientists are beginning to conclude that El Niño periods tend to result in good recruitment of skipjack, yellowfin, and bigeye. On the other hand, recruitment of the more temperate albacore seems to benefit from a La Niña situation. These ideas appear consistent with the good/poor fishing observed after Niño/Niña periods and bring us closer to being able to predict tuna abundance.

The prevalence of El Niño periods in recent years (and subsequent good recruitment of some tuna species) is wonderfully consistent with the results of stock assessment modeling (later in this report) which suggests that recent increases in tropical tuna catches are at least partly due to above-average recruitment in the past two decades.

12.2 The Effects of Tuna Fishing on the Ecosystem Environment

Having seen above the large effects that environmental influences can have on the tuna fisheries, we now turn to the effects of tuna fishing on the ecosystem itself.

One of the key concepts in dealing with this issue is the idea that removing upper-level predators can have a major impact on the pelagic ecosystem. Tuna fisheries take not only tuna from the environment, but also other species such as sharks and billfish. Although there may be concern that these fish may become over-exploited, there is also the worry that, because these large animals are likely to have a major role in structuring the pelagic ecosystem, their removal can alter the system, perhaps in a detrimental manner.

SPC scientists are aware of this concern and are actively considering the issue of the ecosystem effects of tuna fishing. In fisheries management worldwide, there is a general trend towards conserving the structure, diversity, and functioning of ecosystems. The situation is, however, quite complex in the pelagic environment and requires a good knowledge of the predator-prey relationships, food webs, habitats, and the effects of fishing on both target and non-target species. The data now available on these relationships in the pelagic environment does not allow definitive statements to be made on ecosystem effects of removing upper-level predators. In fact, the existing information suggests more “bottom-up than top-down” influence; that is, that the amount nutrients and small food organisms in the ocean have by far the most dominant role in structuring the ecosystem than the upper level predators.

The above should not be taken to dismiss the topic. On the contrary, possible ecosystem effects of tuna fishing are quite important and the information and tools necessary to study the effects should be acquired. This includes obtaining more information on tuna fishing by-catch, establishing priorities for ecosystem monitoring, and developing models to analyze the relevant information.

13. Methods for Assessing the Condition of the Tuna Populations

A fish population is hard to assess because it is usually not possible to count them directly. In this respect, tuna are especially difficult because they occur far from land and often very deep in the ocean. Indirect methods must be used to determine how much tuna is present, or more importantly, the change in the amount of tuna and why the change is occurring.

Methods that have been used to study tuna (*and what information these can give us*) include:

- Sampling the size frequency of tuna in the catch *(information on growth, the amount of juvenile fish growing into a fishable size, and how one kind of fishing can impact another)*
- Marking tuna with plastic tags *(information on growth, movement, mortality, and the impacts of fishing)*
- Determining the total tuna catch and change over time (*can reflect a change in the overall tuna population)*
- Determining the amount of fishing effort (such as vessels days) and change over time (*when combined with total tuna catch (catch per unit effort), it can give a better idea of changes in a tuna population than just total catch alone)*

Each of the above simple methods (and several others) have been used to obtain indications about the condition of tuna populations. For example, because the total skipjack catch in the WCPO region has been increasing for many years, this could suggest that the underlying population is likely to be healthy. The drop of catch per unit effort in longlining for bigeye has been used as evidence that this population has been declining and could be suffering from excessive fishing.

It is important to note that none of the above simple assessment methods taken by itself is conclusive – when a change is noticed in one indicator, there are often several possible explanations of why that change is occurring. For example, an increase in the average skipjack catch from a day of purse seine fishing could be explained by an increase in the tuna population. It also could be due to the purse seine operators becoming more skilled at catching fish (gear innovation, or greater experience in an area). If information on the situation can be added from other study methods, we can be more sure of the underlying reasons for a change. Combining many observations from all the relevant methods would be best, if that were somehow possible.

This is a difficult job, but the way it is made possible is by the use of what is known as a model. A model is a simplified description of a system using mathematical expressions that can be programmed on a computer. Relying on the idea that anything that is observed in nature can be quantified, several different types of observations relevant to assessing tuna can be expressed mathematically and incorporated into a single description. Tuna scientists working for SPC have developed a sophisticated fishery model, known as MULTIFAN-CL (see box), to assess the condition of the tuna populations in the region.

Box: The Development and Use of MULTIFAN-CL

The Oceanic Fisheries Programme at SPC in Noumea has been studying the condition of the tuna population in the region since the late 1970s. In the 1990s SPC staff and contracted consultants worked on a fishery model to assess the condition of the region’s tuna resources. The model, which came to be known as MULTIFAN-CL, has:

- As inputs - many different types of data affecting the population, such as those dealing with tuna catch, fishing effort, size composition.
- As outputs - present and future trends in tuna biomass, exploitation rate, and potential yields from the fishery.

The important point is that the model integrates many different types of information into a single model. The early versions of MULTIFAN-CL were developed for an analysis of South Pacific albacore. In subsequent versions of the model new features have been added, such as geographic aspects, fish movement and tagging data. SPC staff have subsequently applied the model to all four main species of tuna in the region as the main stock assessment tool.

Scientists in other regions are using MULTIFAN-CL, or closely related models, for tuna assessment purposes. Modifications of the SPC-developed model are now being used by researchers to assess such diverse fishery resources as north Pacific groundfish, lobsters in the northwest Hawaiian Islands, and pelagic sharks.

14. Maximum Sustainable Yield

An overview discussion of tuna stock assessment would be incomplete without some mention of the concept of maximum sustainable yield (MSY). In simple terms, the concept indicates that, as fishing pressure increases on an under-exploited stock, the amount of fish harvested can be increased to a certain point, after which the yield declines as fishing pressure increases. At that point, referred to as MSY, the amount of fish yielded over the long-term is at a maximum.

Another way of thinking of MSY is that, with very little fishing on a virgin fish population, the harvest would obviously be very small. A huge amount of fishing could wipe out that same fish population and the subsequent harvest would also be small. Somewhere between these two extremes in fishing pressure there is a point (MSY) at which the long-term harvest is greatest.

The MSY concept can be quite useful in that it can convey important ideas. A major drawback of MSY is that it over-simplifies a complex situation. Applied to tuna, it assumes that other factors known to affect the yield from tuna fisheries (for example, oceanographic conditions mentioned Section 13.1) remain constant (or at least can be represented by an average situation), something that definitely does not occur in nature. Another drawback is that in fishery management MSY often becomes a target to strive towards, when the reality is that at MSY, profits for the fishing activity may be small or non-existent. ("good sustainable catch levels, but all fishers going broke").

Despite the shortcomings of MSY, the concept is likely to be around for a long time. MSY is embedded in the Law of the Sea Convention and, in this region, it is incorporated in the fisheries legislation of several countries, including that of the Marshall Islands, Nauru, Papua New Guinea, and Tonga.

What can be concluded about MSY? We can say that the MSY concept can be a useful tool in fishery work, especially serving as a benchmark understandable by the general public - but it is important that its shortcomings are recognized and compensated for.

15. Assessing the Tuna in the WCPO

Tuna scientists at SPC periodically assess the condition of the four main species of tuna in the region. Various types of documents on the subject are produced for different purposes. For Pacific Island countries, two of the most useful of the assessment publications are *"The Western and Central Pacific Tuna Fishery – Overview of Status of Stocks"* and the *"Executive Summary of the Standing Committee on Tuna and Billfish"* [2]. These are normally issued on an annual basis.

With respect to stock status, both the above reports present three types of information for each of the four tuna species:

- Trends in catch and in catch per unit effort
- Trends in the size composition
- Results of stock assessment using MULTIFAN-CL analysis

[2] The SCTB provides a forum for scientists and others with an interest in the tuna and billfish stocks of the WCPO to meet to discuss scientific issues related to data, research, and stock assessment.

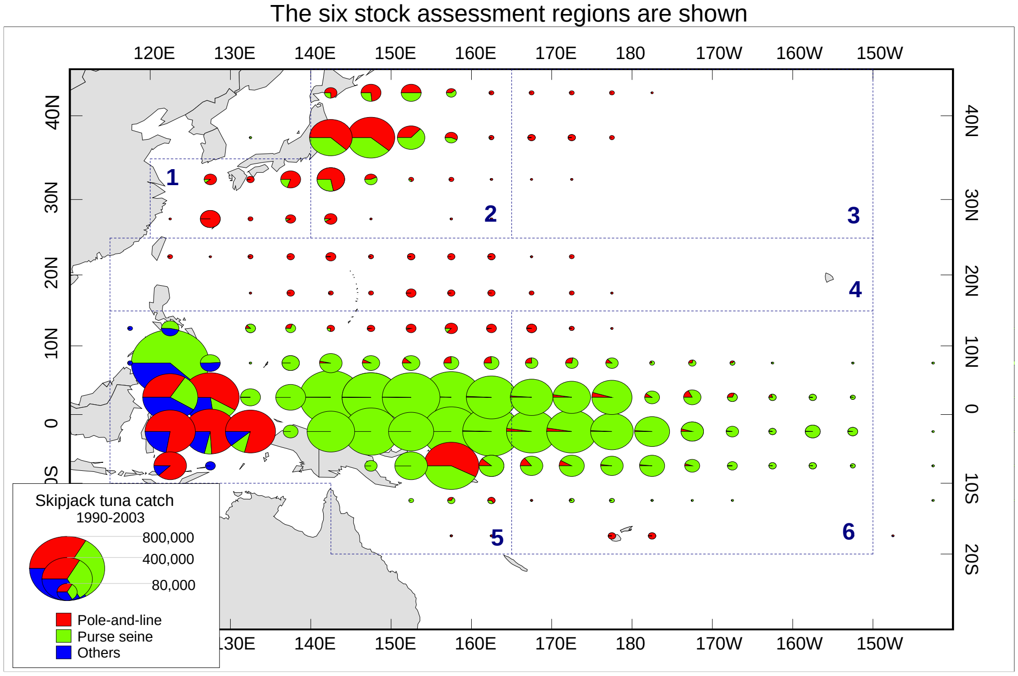
The following is a summary of the most recent information from the *Overview* and the *Executive Summary.*

15.1 Skipjack Status

Catches of skipjack in the WCPO have increased steadily since 1970, more than doubling during the 1980s, and continuing to increase in the subsequent years. Annual catches exceeded 1.2 million tonnes in three of the last five years. The catch in 2003 was estimated to be 1,250,000 metric tonnes (mt), a slight decrease on the 2002 catch; 75 % (940,000 tonnes) was taken by purse seine gear, 19% (242,000 tonnes) by pole-and-line gear and 6% (approximately 70,000 tonnes) by other gears. Catch per unit effort (tonnes per day fished) for major purse seine fleets, except the U.S. fleet, continues to be at a high level, slightly decreased from 2002 level, being more than 20 tonnes/day fished in 2003.

Distribution of Skipjack Catch, 1990–2003

The six stock assessment regions are shown



The size composition of the skipjack catch (Section 12) does not appear to suggest major underlying trends in the population, but rather changes in fishing gear and fishing strategy. The dominant mode in the overall skipjack catch generally falls in the 50 to 60 cm range, corresponding to 1 to 2 year-old fish.

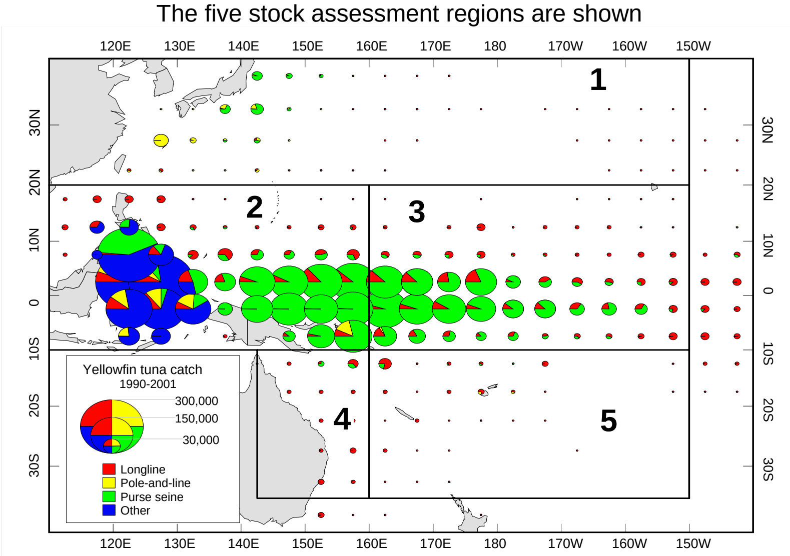
While skipjack tuna stock biomass in the WCPO shows considerable inter-annual variation, overall trends in stock biomass are either stable or increasing. The application of the MULTIFAN-CL assessment model shows that while fishing mortality has increased significantly over time, the overall estimates of recent fishing mortality remain considerably less than the corresponding estimates of natural mortality. The percentage reduction in stock biomass attributable to the fishery has been 20 to 25% in recent years. Present levels of stock biomass are high and recent catch levels are easily sustainable under current stock productivity conditions.

15.2 Yellowfin Status

Since 1990, the estimated yellowfin tuna catch in the WCPO has varied between 320,000–500,000 mt with annual catches exceeding 400,000 mt each year since 1997. The 2003 catch of yellowfin tuna in the WCPO was estimated at 456,947 mt. This level of catch represents the second highest catch on record, and is mainly due to an increase in the Philippines domestic purse seine and handline catches. The purse seine catch of yellowfin was estimated at 214,535 mt or 47% of the total WCPO yellowfin catch. The longline catches since 1990 (60,000–80,000 mt) have been well below catches taken in the late 1970s to early 1980s (87,000-117,000 mt). The 2003 longline catch is estimated to be 67,490 mt, or 15% of the total yellowfin catch.

Distribution of Yellowfin Catch, 1990-2001

The five stock assessment regions are shown



Catch per unit effort of yellowfin by the Japanese longline fleet (the fleet that has the most historical data) displays high inter-annual variability and regional differences, with an overall decline since the early 1950s in the equatorial WCPO but little or no overall trend in more temperate regions. Trends in catch per unit of effort of yellowfin by purse seine gear is characterized by strong inter-annual variability, by differences amongst the various national fleets, and by influence from oceanographic conditions, with increased catch rates during El Niño periods.

Size composition data of the yellowfin catch shows:

- The domestic surface fisheries of the Philippines and Indonesia take large quantities of small yellowfin in the range 20–50 cm.
- The purse-seine catch of adult yellowfin tuna, on average, has been higher than the longline catch over the past 10–15 years.
- The amount of very large yellowfin in the longline catch (> 150 cm) appears to have declined since the 1960s.

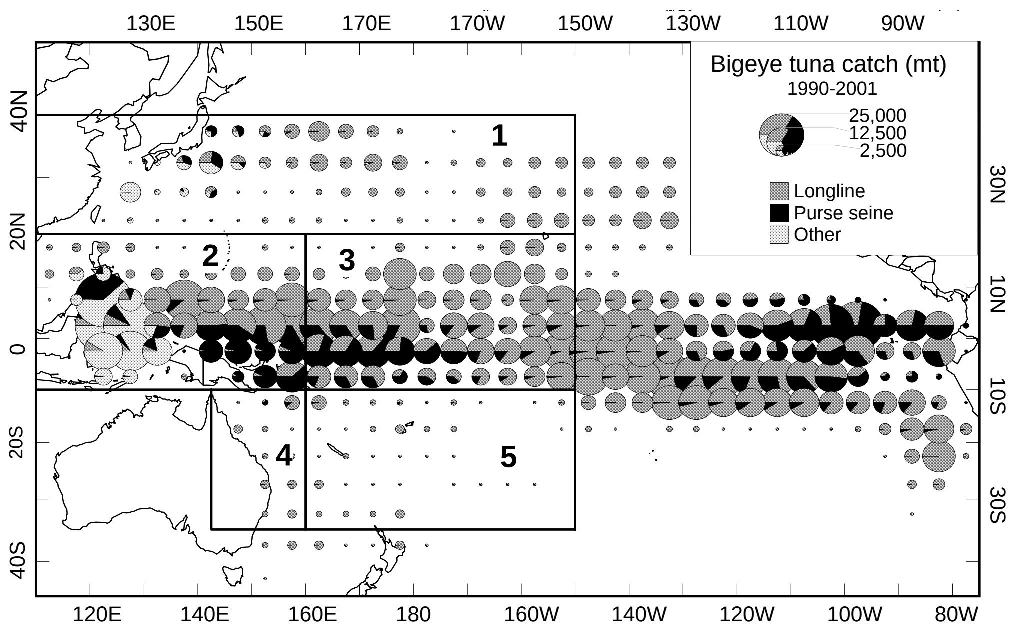
Total yellowfin biomass has declined relatively steadily over the period that has been analyzed by the MULTIFAN-CL model (1950–2002), with the largest decline in biomass occurring in the equatorial regions. The yellowfin in the WCPO is probably not being over-fished, but the stock is likely to be nearing full exploitation and any future increases in fishing mortality would not result in any long-term increase in yield and may move the yellowfin stock to an over-fished state. The assessment also indicates that the equatorial regions are likely to be more fully exploited, than the temperate regions. The Indonesian fishery has the greatest impact on yellowfin depletion, particularly in its home region.

15.3 Bigeye Status

The total bigeye tuna catch in the WCPO for 2003 was 96,000 mt, the lowest for 7 years. This followed a 2002 catch of 124,107 mt, the highest ever recorded. Available statistics indicate that 60% of the 2003 WCPO catch was taken by longline, and most of the remainder by purse seine (21%) and by the domestic fisheries of Indonesia and Philippines and others (18%). Bigeye catch per unit effort derived from longline data indicates a sharp decline during the early stages of the fishery. Depending on the region (five bigeye assessment regions on the chart below) and any corrections applied to the data to account for changes in the fisheries, the bigeye catch per unit of effort has been stable or declining in recent years.

Distribution of Bigeye Catch, 1990-2001

The five stock assessment regions are shown



Bigeye longline size composition data over several decades show a considerable decline in the proportion of large (>150 cm) fish in the catch, particularly during the early period of the fishery. The surface fisheries of the Philippines and Indonesia take large quantities of small bigeye in the 20-50 cm range.

MULTIFAN-CL analysis indicates that total biomass of bigeye tuna has declined by about 30% during the 1950s and 1960s and remained relatively stable in the subsequent years. Currently fishing, particularly by longline, is having a large impact on the biomass level. The impact of fishing is highest in the equatorial area (regions 2 and 3 above). However, despite the high fishery impact (increasing fishing mortality), the model indicates that total biomass has remained relatively stable due to the steady increase in annual recruitment over the last two decades. The current level of exploitation appears not to be sustainable in the long term, unless the high recent recruitment is maintained.

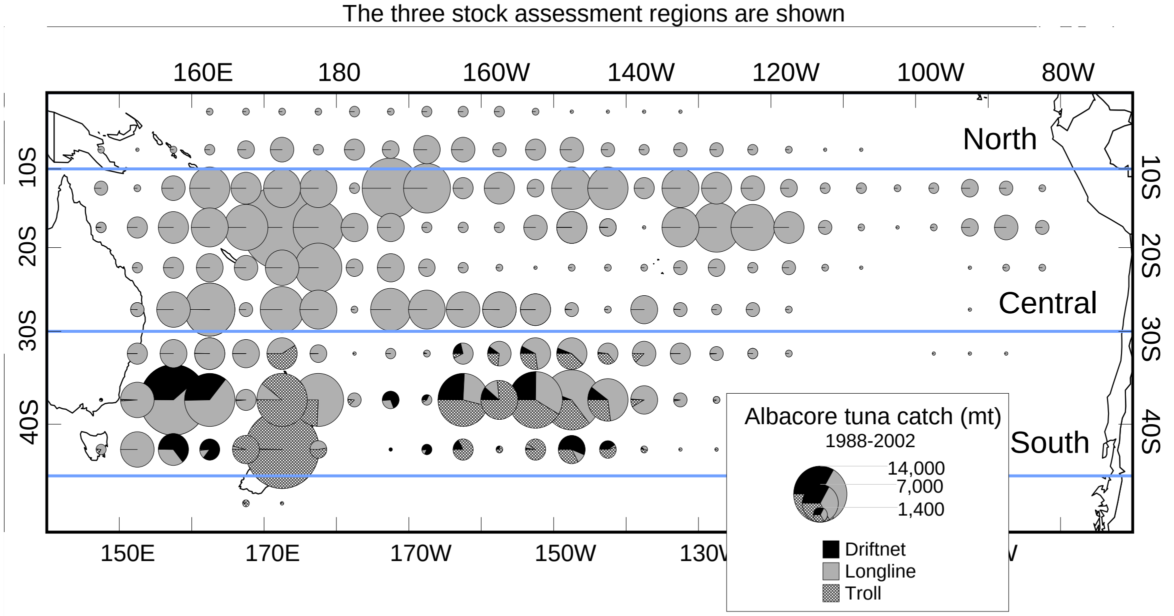
15.4 South Pacific Albacore Status

Historically, south Pacific albacore catches have generally fallen in the range of 25,000 to 50,000 mt, although a significant peak was attained in 1989 (52,576 mt), when driftnet fishing was occurring. Total south Pacific albacore catches have shown an increasing trend since the mid-1990s. Catches from longline fleets based in Pacific Island countries have increased in recent years and by 2002, these fleets accounted for 50% of the total longline catch. Catch per unit of effort by the longline fleet with the longest fishing history declined from the late 1960s to the late 1980s in all areas, but has increased somewhat in the 1990s after a low point in 1990. Since 1999, the nominal catch rate has been relatively stable in the central area, increasing in the southern area, and dropping in the northern area. Recent trends in the catch per unit effort from the Pacific Islands domestic longline fisheries generally indicate declines, but have improved in 2004. Catch rates in the New Zealand troll fishery have been stable in the 1990s.

Longliners catch larger albacore, with the size distribution typically comprising fish of 90–100 cm. Troll catches are of smaller albacore, typically 50–85 cm in length. Size composition varies from year to year, but no trends are evident over the past five years.

Distribution of Albacore Catch, 1988-2002

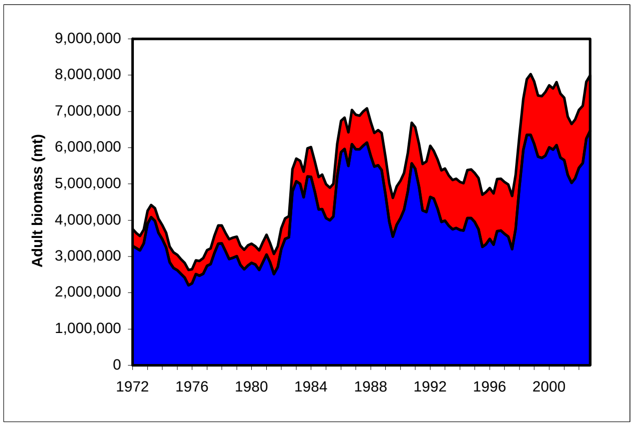
The three stock assessment regions are shown



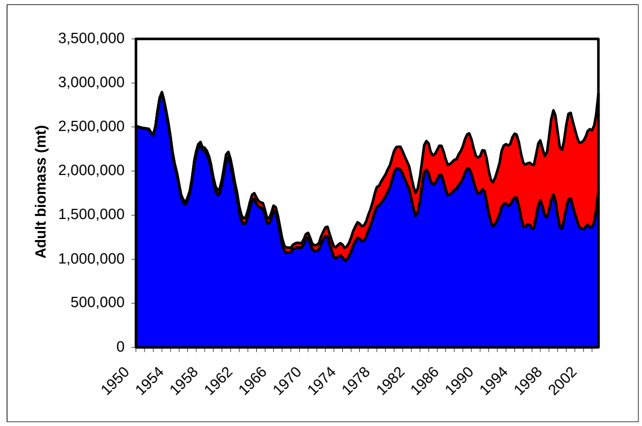
MULTIFAN-CL analysis indicates that the South Pacific albacore tuna stock declined moderately since the early 1980s. This decline in stock biomass was mainly due to the reduced number of juveniles entering the fishery, and the slight recovery in the mid-1990s was due to improved recruitment. The declines in catch rates experienced by some Pacific Island longline fleets in 2003 are likely to be due to changed oceanographic conditions and localised intense fishing. The impact of all fishing on overall south Pacific albacore biomass is estimated to be small, and higher levels of catch could likely be sustained without a risk to the stock. However, fishing (by longline) is concentrated on older fish in the population, and fishing on that segment of the stock has resulted in a reduction of biomass of about 30% in the recent years. Reductions in more heavily fished areas are likely to have been greater. The potential for expansion of the longline fishery for albacore depends mainly on whether vessels can continue to operate profitably at the lower catch rates that will result from such stock reductions.

15.5 Summarizing the Stock Status

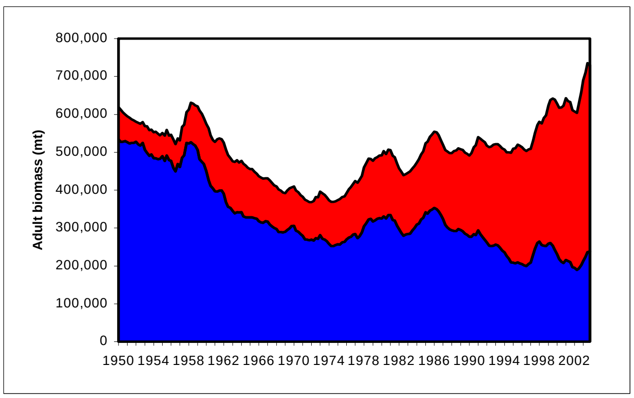
Another way of looking at the tuna stock status is to consider the biomass of the four species of tuna – and what portion of that biomass has been removed by fishing. With MULTIFAN-CL this can be done for the adult fish of the four tuna species in the WCPO:



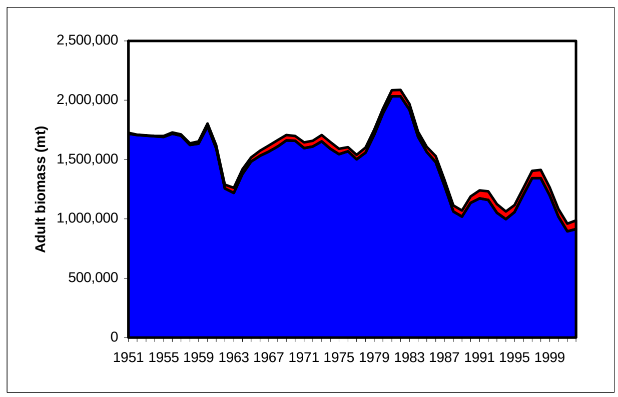
Skipjack



Yellowfin



Bigeye



Albacore

The graphs above show that for skipjack and for south Pacific albacore, the estimated adult biomass (darker blue areas) is much larger than the adult biomass removed by fishing (lighter red areas). Bigeye, however, has been heavily impacted by fishing, as shown by the large proportion removed by fishing.

The stock assessment information on the four species of tuna is summarized in the following table.

WCPO Tuna Stock Status Summary

	Trends in catch	Trends in catch per unit effort	Features of the size composition data	Conclusions incorporating MULTIFAN-CL results
Skipjack 	Catches have increased steadily since 1970, more than doubling during the 1980s	Catch per unit effort for most purse seine fleets continues to be at a high level	Size composition does not appear to suggest major underlying trends in the population	Current levels of stock biomass are high and recent catch levels appear easily sustainable
Yellowfin 	Catches have increased steadily since 1970, more than doubling during the 1980s. The longline catch peaked in the late 1970s and early 1980s, but purse seine catches continue to grow.	Japanese longline fleet catch rates show variability and regional differences, with an overall decline since the early 1950s in the equatorial WCPO but little or no overall recent trend in more temperate regions.	Purse-seine catch of adult yellowfin tuna is greater than the longline catch. The amount of very large yellowfin in the longline catch appears to have declined since the 1960s.	The stock is probably not being over-fished, but is likely to be nearing full exploitation and any future increases in fishing mortality would not result in any long-term increase in yield and may move the stock to an over-fished state.
Bigeye 	Catches show much variation in recent years; The catch for 2003 was the lowest for 7 years. This followed a 2002 catch that was highest ever recorded.	Nominal catch per unit effort declined during the early stages of the fishery but has been fairly stable over recent years.	Size composition data over several decades show a considerable decline in the proportion of large fish in the catch.	Fishing is having a large impact on the biomass level. The current level of exploitation appears not to be sustainable in the long term, unless the high recent recruitment is maintained.
Albacore 	South Pacific albacore catches have been mostly in the range 25,000 to 50,000 mt, although a significant peak was attained in 1989, during the driftnet fishing era. Total south Pacific albacore catches have shown an increasing trend since the mid-1990s.	Longline catch rates declined from the late 1960s to the late 1980s, but increased in the mid/late 1990s. Since 1999, the nominal catch rate has been relatively stable in the central area, increasing in the southern area, and dropping in the northern area.	Size composition varies from year to year, but no trends are evident over the past five years.	South Pacific albacore tuna stock declined moderately since the early 1980s. The impact of all fishing is estimated to be small, and higher levels of catch could likely be sustained. However, longline fishing is focused on the older fish resulting in a biomass of the order of 30% in the most recent years on that segment of the population.

There is considerable geographic variation in stock condition. Both the bigeye and yellowfin assessments show that the impact of fishing is greatest in the equatorial region. For albacore, it appears that, in areas where there are high levels of localised fishing effort, the catch rates appear to fall, at least temporarily.

16. How Do We Know the Tuna Stock Assessments Are Correct ?

It is important to ask this question. On one hand we know that tuna are so vital for the Pacific Islands region. But on the other, many very well-studied fisheries in the world have crashed, some spectacularly.

There is no easy answer concerning the uncertainty associated with the tuna stock assessments (whether the scientists "have got it right"), but the subject can be explored at different levels.

The accuracy of the SPC stock assessments is closely related to the quality of the output of the MULTIFAN-CL model. Scientists have gained confidence in the model in several ways, including comparing the model's predictions with actual observations (examining model fit to data), and by comparing model results to data outside the model. An example of the latter point is comparing tuna growth from MULTIFAN-CL to results from ageing using fish skeletal features.

At a different level, the results of the SPC tuna assessment are critically examined by fishery scientists outside the SPC in various ways:

- A substantial amount of scientific scrutiny occurs at what is known as the Standing Committee on Tuna and Billfish (SCTB). This is a forum for scientists and others with an interest in the tuna and billfish stocks of the WCPO to discuss scientific issues related to data, research, and stock assessment. Much of the meetings of the Committee (held mainly annually on 17 occasions) is about reviewing the SPC tuna assessments.
- The SPC itself periodically commissions independent specialists to review various aspects of its tuna work. The most recent review (September 2001) was carried out by three experts and supported the SPC approach to modeling and tuna assessment.
- SPC results are periodically published in a variety of ways, including refereed scientific journals, where they can be critically reviewed by peers and other interested people.

Such reviews of the SPC tuna stock assessment have generally supported the results. Where there has been valid criticism, efforts have been taken to correct the deficiencies.

Not all fishery scientists agree with the SPC assessments. In a well-publicized article[3] two scientists analyzed Japanese tuna longline data and asserted that large predatory fish biomass today is only about 10 percent of pre-industrial levels. The SPC analysis suggests a depletion of about 40%. Who is correct? The SPC scientists feel that the catch data used in the alternative analysis should have been scrutinized more carefully and that it was wrongly assumed that uncorrected catch rates are a good indicator of tuna population abundance. Although there will always be dissent on tuna stock assessment - a subject so important yet so complex – most knowledgeable outside scientific observers feel that the SPC assessments have the greatest credibility.

On a general level, it is unlikely that it will ever be possible to "prove" the accuracy of the SPC tuna assessments. It is more of a situation in which various types of information can support or refute the results. Feedback to date from various sources has been quite supportive of the SPC assessments.

In another sense, it is possible to think of the situation in terms of risk. There will always be some risk that the tuna assessments are inaccurate, but we can try to reduce the level of risk and/or determine an acceptable level of risk. Presently, the level of risk could probably best be reduced by improving the quality of model input information, especially data on catch and fishing effort. Because the tuna resources are extremely important to the Pacific Islands, it may be wise to be conservative with the level of risk accepted and, should there be a range of results, to shy away from the more optimistic views of stock condition.

[3] Meyers, R. and B. Worm (2003). Rapid Worldwide Depletion of Predatory Fish Communities. Nature 423, 280-283.

Benefiting from experience in fisheries from other parts of the world, it is likely that the greatest risk to the tuna resources may not be inaccurate stock assessments, but rather that governments are unwilling or unable to take action related to the stock assessments.

17. So What Can Be Concluded From The Latest Stock Assessment Information?

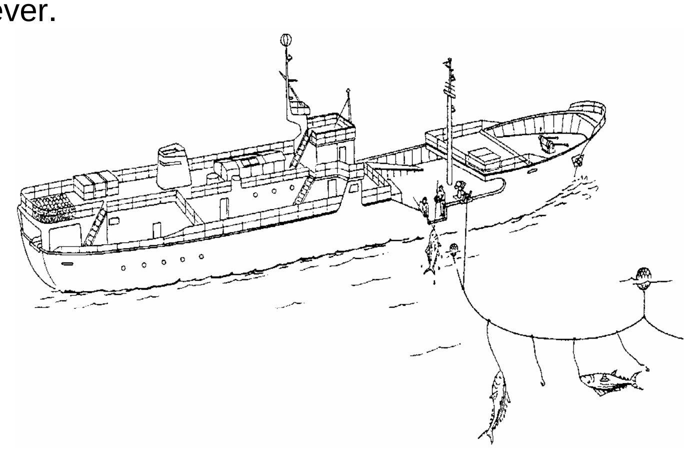
Many years of stock assessment work by the SPC have produced the tuna assessments that are summarized in the table above. Those assessments should be considered the best available information at the present time. In other words, the tuna resource condition is not likely to be much clearer anytime soon.

The tuna assessments are associated with both important messages but also considerable uncertainty. The important messages are:

- Current catch levels of skipjack appear to be easily sustainable
- Current catch levels of south Pacific albacore are likely to be sustainable
- Current catch levels of yellowfin represent a fully exploited situation. Yellowfin in the equatorial regions are probably being exploited at a much higher rate than those in subtropical areas.
- Current catch levels of bigeye appear to be sustainable only with continued high recruitment

As the various tuna species of the region become more fully exploited, recruitment is assuming a key role in determining the sustainability of the present catch levels. With respect to recruitment, the following observations can be made:

- It is known that recruitment for the four important tuna species can be highly variable.
- It is becoming clear that in recent years, recruitment has been relatively high for skipjack and for the two species under pressure (yellowfin and bigeye).
- Oceanographic events have a key effect on recruitment (probably more so than the amount of spawning individuals) and there is a growing feeling that El Niño conditions are favourable for the two species under pressure.
- A major unknown is our lack of ability at the present time to predict recruitment, or even the oceanographic events that may shape it. In terms of the future, it can be stated that it is not likely that conditions favourable to recruitment for skipjack, yellowfin, and bigeye will continue forever.



18. Considering the Tuna Assessments, What Action Should Be Taken?

Although recruitment is very important, there is little we can do to control this process, especially since oceanographic events are likely to have a dominant effect on recruitment. What we can do is place various controls on fishing activity.

With respect to what action should be taken, the current thinking is that measures should be taken to reduce the catches of bigeye and yellowfin, especially the juveniles. The need for catch and/or effort reduction follows directly from the tuna assessments, which show a large reduction in biomass due to fishing. The focus on juveniles is due largely to:

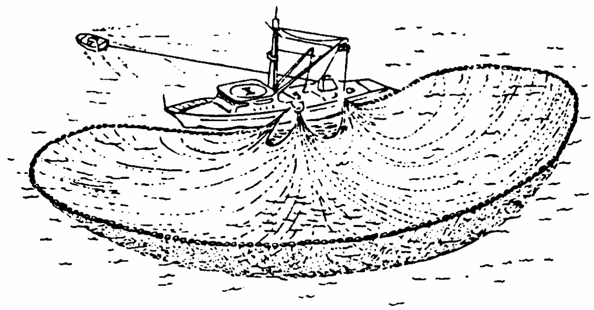
- Economics – the small fish have a low value while the large individuals are extremely valuable.
- Population dynamics - foregoing catches of juveniles should ultimately result in higher stock levels and better catches of larger fish.

Formulating appropriate measures for reducing fishing pressure on yellowfin and bigeye is under consideration at the present time by the governments of Pacific Island Countries. The ideal control on fishing activity would be something that is easy and cheap to apply and enforce, not be a major burden to the fishers, not reduce the benefits to the country in which the fish are caught, and result in a substantial reduction in fishing mortality on these tunas. Fishing controls can be classified into two broad categories:

- Input controls – measures such as limiting the number of vessels, fishing time, fishing area, or gear types
- Output controls – measures such as limiting the total catch or subset of the catch, such as small fish

Many measures to reduce the catch of bigeye and yellowfin in the Pacific Islands region have been studied, but the ones now under active consideration include:

- Limits or bans on purse seining around floating objects – Because floating objects (both anchored and drifting, and natural/man made) attract large quantities of tuna, purse seine vessels often set their nets around these objects. These sets however, result in much greater amount of juvenile yellowfin and bigeye being caught.
- Limits on longlining – At present there are no limits on the number of longline vessels that can operate in the region. Although longlining does not usually capture juvenile yellowfin and bigeye, this fishing technique is thought to be responsible for most of the biomass reduction of yellowfin and bigeye, hence some controls are considered necessary.
- Limiting purse seining – Pacific Island Countries in the prime purse seine area have had a scheme in place for several years in which the number of purse seine vessels is limited to 205. Presently under consideration is a proposal to change the scheme to one in which the number of purse seine days is limited.



What do the stock assessments mean for fishing companies and investors? The stock assessment work is showing that fishing effort on bigeye should be reduced and that on yellowfin is approaching a maximum. How that effort should be reduced or be frozen falls into the domain of fisheries management – balancing the various choices and trade-offs in view of the objectives that have been set. In simple terms, stock assessment will give information on the size of the tuna pie (and maybe, any expanding or shrinking of the pie), but it gives much less information on how the pie should be divided up between countries, companies, or catchers.

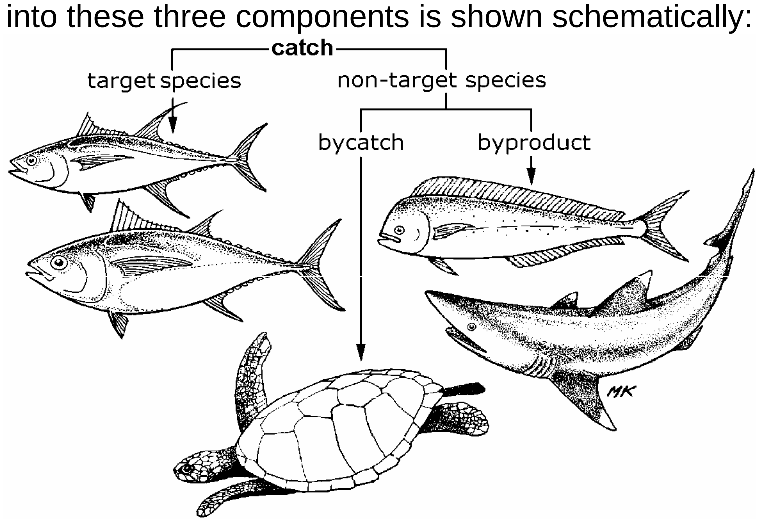
In view of the aspirations of many Pacific Island countries to promote domestic tuna industry development, encourage local business activity, and increase employment, it would seem that in any scheme to reduce tuna fishing effort in this region, Pacific Island Countries would favour those fishing operations and companies that contribute to these economic goals.

19. Other Important Aspects of the Tuna Resources of the Region

19.1 Non-Target Species

Most types of fishing, including tuna fishing, catch species other than those that are intended to be captured. These fish and other animals are collectively known as non-target species. In tuna fishing the non-target species can be divided into those species that have some commercial value (referred to as by-product) and those species that are unwanted (referred to as by-catch) because they have no commercial value or are protected by law.

The division of the catch into these three components is shown schematically:



The amounts and type of non-target species from tuna fishing in the Pacific Islands area varies between the various fishing gear. SPC studies show:

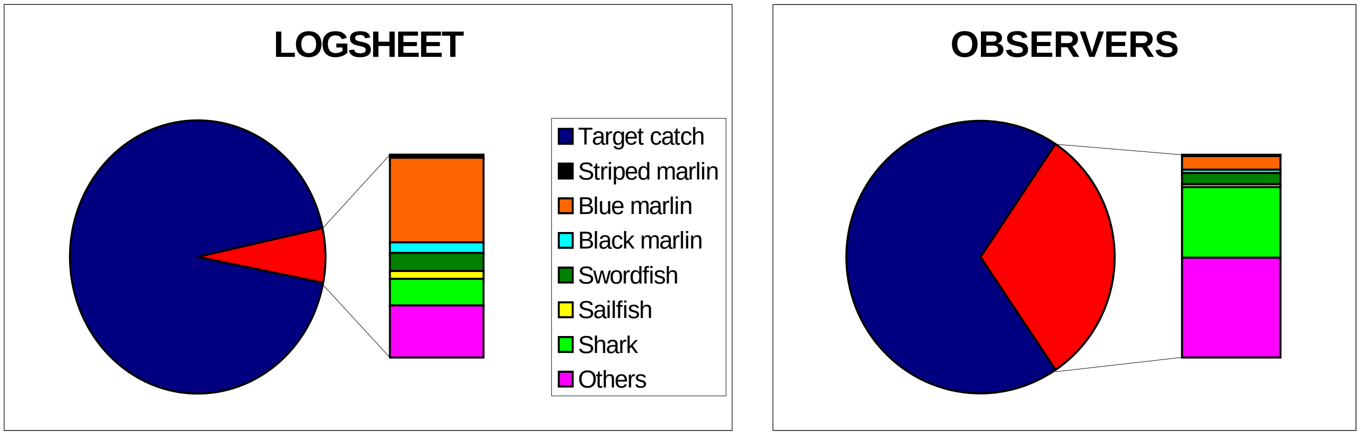
- In the purse seine fishery from 0.35 to 0.77 per cent of the total catch for fishing on tuna schools not associated with floating objects is by-catch. For sets on tuna aggregating around floating objects, the level is higher at an estimated 3.0–7.3 per cent. The most common by-catch species observed in floating object sets are amberjack (*Seriola rivoliana*), mackerel scad (*Decapterus macarellus*), rainbow runner (*Elagatis bipinnulata*), drummer (*Kyphosus cinerascens*), mahimahi (*Coryphaena hippurus*) and ocean triggerfish (*Canthidermis maculatus)*.
- In the longline fishery over 50 non-target fish species have been observed in the tropical and sub-tropical waters of the WCPO. In the SPC study there were insufficient data to estimate relative quantities. The non-target fish species can be categorized into shark (21 species), non-target tunas (7 species), billfish (6 species) and other fish (21 species). The blue shark (*Prionace glauca*) was observed as the most common shark species taken throughout the WCPO.
- The pole-and-line fishery produces much less by-catch than purse seining or longlining. The most common fish species are mahimahi, rainbow runner, and the non-target tunas.

Why worry about non-target species? There are several reasons why fisheries scientists, fishers, and the general public are concerned about tuna by-catch issues, including the capture of endangered species and the effects on the pelagic ecosystem.

The main concern is with marine turtles and sharks which are taken occasionally by tuna longlining. In an SPC study 2,143 observed longline sets in the western tropical Pacific during the 1990s were analyzed. A total of 83 turtles was recorded, with all but one released. Of those released, 27% were released dead, while 58% were described as alive and healthy, 8% injured/stressed and 6% barely alive. Turtle by-catch by purse seiners is less well-documented and only available from observer data, but appears to be low, with only 2.5 turtles being caught per 1,000 sets. In general, the results of the turtle studies show less frequent capture of these animal than was feared a few years ago

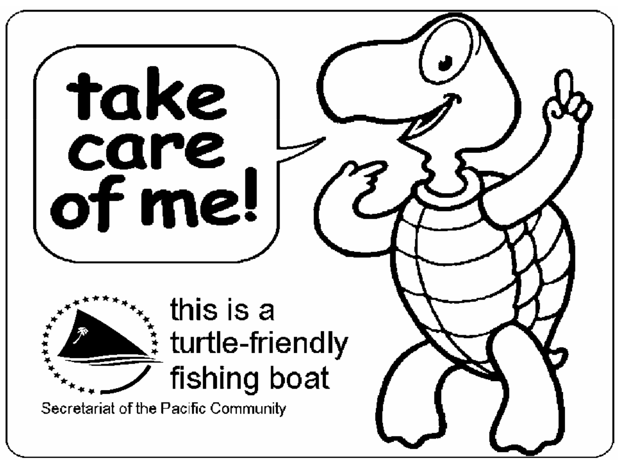
As mentioned in Section13.1 above, there is some concern that tuna fishing and its associated catch of sharks can have an effect on the pelagic ecosystem. Although recent studies suggest that the sharks commonly caught in tuna fishing are not over-exploited, there is some concern that, because these large animals are likely to have a major role in structuring the pelagic ecosystem, their removal can alter the system, perhaps in a detrimental manner.

Coverage of the tuna fleets by fishery observers is especially important for the by-catch issue. The pie charts below (from SPC longline data) indicate that vessels report on their catch logsheets less by-catch than fishery observers see on similar fishing trips.



Action is underway to address by-catch issues. The general emphasis on dealing with by-catch by Pacific Island governments and regional organizations has been to:

- Learn more about tuna by-catch to determine the size of the problem (for example, more coverage of fishing activities by fishery observers)
- Begin implementing measures to reduce by-catch (formulating plans to reduce purse seine fishing on floating objects)
- Mitigate any negative effects of by-catch (teaching fishers how to release hooked turtles).



19.2 Tuna Fishing in Indonesia and the Philippines

The tuna fisheries of Indonesia and the Philippines are closely related to those of the Pacific Islands. Presently, about one-third of the tuna catch in the WCPO region is taken in those two SE Asian countries. Tuna tagging studies have shown substantial movements of fish between Indonesia/Philippines and the western part of the Pacific Islands region. Recent stock assessment work shows that tuna fishing in Indonesia and the Philippines are having a large impact on the stocks in the WCPO region. For example, SPC studies show that the Indonesian fishery is the greatest contributor to the depletion of WCPO yellowfin stock.

This shows that cooperation between SE Asia and the Pacific Islands is important for tuna stock assessment and subsequent management measures to assure sustainability of the resources.

There are, however, problems. Although those countries are major producers of tuna (Indonesia harvests more tuna from its waters than any other country), statistics on tuna fishing in those two Asian countries are not very good, with those from Indonesia being especially troublesome. If management action is required (for example, to prevent bigeye over-exploitation), Indonesia and the Philippines would probably experience much more difficulty in applying controls on their domestic fisheries and in cooperating internationally than would be case for Pacific Islands governments.

Fortunately, there have been some recent developments. International funding has become available to improve catch statistics in the Philippines, and hopefully soon in Indonesia. Both countries have agreed to begin formulating arrangements for managing tuna in the WCPO region. Still, much work is required before plans and programmes result in actual improvements.

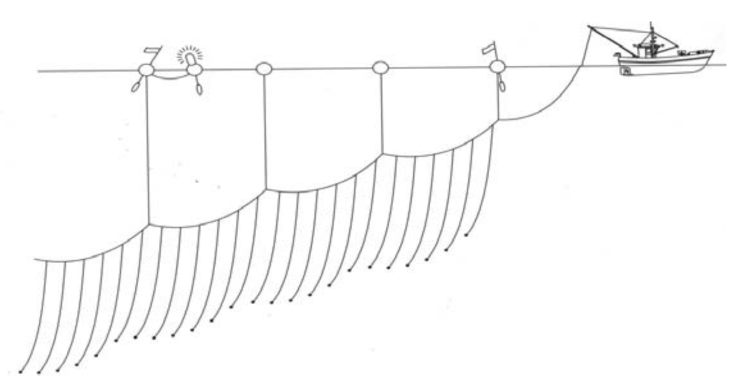
19.3 The Precautionary Approach

In fisheries management, the term “precautionary approach” is often heard. The term is written into some of the major international fishery management treaties and appears in the fisheries legislation of the Federated States of Micronesia, the Marshall Islands, Nauru, Papua New Guinea, and the Solomon Islands.

The popular use of the term had its origins in the environment movement. With regards to fisheries, by international agreement[4], the precautionary approach has been extended to mean that the absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment.

In the WCPO tuna fisheries, a precautionary approach seems to be especially applicable to the bigeye resource. The best scientific information available shows that current levels of bigeye fishing mortality carry high risks of over-fishing, current catch levels of bigeye appear to be sustainable only with continued high recruitment, and that conditions favourable to this recruitment will not continue forever.

Although there are still large uncertainties associated with the stock assessment of bigeye in the WCPO, the precautionary approach is about taking management action before such uncertainty is resolved.



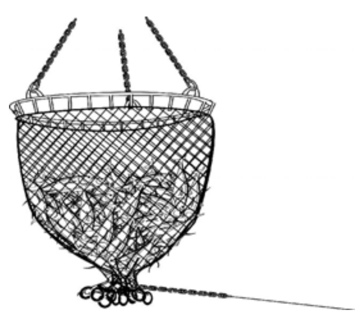
[4] The Code of Conduct for Responsible Fisheries

19.4 International Cooperation in Tuna Management

We have seen in Section 6 above that research on tuna must cover a large geographic area. Similarly, any management measures to conserve the tuna cannot be fully effective unless they cover a broad region. Accordingly, the Pacific Island Forum Fisheries Agency facilitates cooperation in tuna resource management among Pacific Island Countries.

The region's first conservation-oriented management move in the tuna fisheries was the Palau Agreement for the Management of the Western Pacific Purse-Seine Fishery. In the late 1980s Pacific Island countries became concerned that the yellowfin stock was approaching a fully-exploited condition and that action should be taken to reduce catches. FFA and a sub-group of countries responded and, following two years of negotiations, the Palau Arrangement was signed in October 1992 by Federated States of Micronesia, Marshall Islands, Nauru, Palau and Tuvalu. Kiribati and Papua New Guinea signed the following year. The Arrangement entered into force in November 1995. The Arrangement places a ceiling on the number of purse-seine licenses that can be issued by the seven Pacific Island countries party to the agreement. The limit was originally set at 164 vessels and progressively increased. The Palau Arrangement presently consists of four categories of purse seine vessel licenses totalling 205. For several years there has been discussion of modifying the Palau Arrangement so that purse seine vessel fishing days (rather than vessel numbers) is used as the basis for management.

In the mid-1990s there was a growing awareness of the need for a tuna management agency that would cover an area larger than that encompassed by Pacific Island countries and which would include countries that have vessels which fish in the area, such as Japan and the USA. After four years of complex negotiations between the coastal States of the Western and Central Pacific and States fishing in the region, the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean was opened for in September 2000. The objective of the Convention is to ensure, through effective management, the long-term conservation and sustainable use of highly migratory fish stocks in the western and central Pacific Ocean in accordance with the 1982 United Nations Convention on the Law of the Sea and the 1995 UN Fish Stocks Agreement. For this purpose, the Convention establishes a Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean, now known as the Western and Central Pacific Fisheries Commission. The Convention entered into force on 19 June 2004. As of October 2004, the following States had ratified or acceded to the Convention: Australia, Cook Islands, Federated States of Micronesia, Fiji Islands, Kiribati, Marshall Islands, Nauru, New Zealand, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga and Tuvalu. The Commission, which will have its headquarters in Pohnpei, Federated States of Micronesia, held its first meeting in December 2004.



20. "Take Away" Messages on the Tuna Resources of the Region

Four species of tuna are of major commercial importance in the Pacific Islands: skipjack, yellowfin, bigeye, and albacore. These four tunas are quite distinct with respect to many properties such as how they are captured, the amount presently captured, the size of the populations, and the end use of the product.

The tuna catch in the Western and Central Pacific Ocean has increased tremendously during the last three decades – almost 4-fold since 1972. With respect to gear, purse seining is responsible for most of the increase. With respect to species, skipjack (and to a lesser extent yellowfin) is responsible for most of the increase. Other important aspects of the tuna catch are:

- Much of the catch occurs within the exclusive economic zones of FFA member countries.
- The catch is not evenly distributed across the region - most of it is taken close to the equator.
- The large share in Indonesia and the Philippines is also significant, because tagging data show much interchange of fish between the waters of those countries and that of the Pacific Islands.
- The catch on the high seas is also very important as placing any controls on that fishing is more complex than doing so in waters under the control of a single country.

The climatic event known as El Niño has a striking impact on tuna, affecting their abundance, distribution, and ease of capture. It is also appears that El Niño periods (which have been dominant in the last decade) tend to result in good recruitment of skipjack, yellowfin, and bigeye.

Fishery scientists at SPC rely on mathematical models to assess the condition of the tuna populations in the Pacific Islands region. Their modeling integrates many different types of data affecting a tuna population (for example, tuna catch, fishing effort, size composition) to estimate several important features relating to tuna, such as trends in tuna biomass, exploitation rate, and potential tuna yield. Feedback to date from various sources has been generally supportive of the models developed and the associated SPC tuna assessments. The important messages related to tuna stock assessment in the WCPO region are:

- Current catch levels of skipjack appear to be easily sustainable
- Current catch levels of south Pacific albacore are likely to be sustainable
- Current catch levels of yellowfin represent a fully exploited situation
- Current catch levels of bigeye appear to be sustainable only with continued high recruitment

The management implication of this stock assessment information is that measures should be taken to reduce the catches of bigeye and yellowfin, especially the juveniles. The precautionary approach would suggest that such action to protect these tunas be taken sooner rather than later.

Will there be tuna for tomorrow? The research has been carried out, the results have been presented, and required management action has been suggested. The question of whether the tuna resources of the Pacific Islands continue to provide maximum benefits for future generations appears to lie at this point in time, not with the finer points of stocks assessment, but rather in the hands of government leaders. Benefiting from experience in tuna fisheries from other parts of the world, it is likely that the greatest risk to the tuna resources in the Pacific Island region is that governments are unwilling or unable to take the required management action.

21. Acknowledgements and Abbreviations Used in the Report

Most of the information and illustrations in this report have appeared in various SPC reports over the years. With kind permission of the SPC, maps and drawings from the Oceanic Fisheries Programme and the Development, Training, and Information Sections were adapted for this report. Much use was made of the excellent drawings done by Mike King for SPC. The following is also acknowledged:

- Tuna drawings and vessel drawings originally by FAO
- Tuna drawing from FFA's Solomons Tuna Management Plan
- The El Niño schematic drawings were re-drawn by SPC from those of Heidi Merschen appearing in National Geographic (Vol 195 (3): 72-95)
- Sketches done by SPC staff: Jipé Le-Bars and Youngmi Choi
- Cover photograph by William Boyce – WWW.BOYCEIMAGE.COM
- Alternative scientific opinion was furnished by Jim Ianelli

Abbreviations used in the report

- EEZ – exclusive economic zone
- FFA – Forum Fisheries Agency
- MSY - maximum sustainable yield
- MT – metric tonne
- PNG – Papua New Guinea
- SCTB - Standing Committee on Tuna and Billfish
- SPC – Secretariat of the Pacific Community
- WCPO – Western and Central Pacific Ocean